*Iskandar., et al. Belitung Nursing Journal. 2018 June;4(3):343-349*
Received: 23 March 2018 | Revised: 7 April 2018 | Accepted: 13 May 2018
http://belitungraya.org/BRP/index.php/bnj/



**ORIGINAL RESEARCH** **ISSN: 2477-4073**

# INCREASING FOOT CIRCULATION WITH ELECTRICAL STIMULATION IN PATIENTS WITH DIABETES MELLITUS

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**Abstract**
**Background:** Peripheral arterial disorders in diabetes mellitus is a common complication that often occurs and can develop into diabetic foot ulcers. High blood sugar levels in people with diabetes mellitus can cause increased blood viscosity resulting in thickening of the capillary membrane, where erythrocytes, platelets and leucocytes are attached to the blood vessels. Electrical stimulation by placing electrodes in the calf muscle is one of the measures to increase foot blood flow that can reduce the poor foot circulation.
**Objective:** This study aims to determine the effect of electrical stimulation in improving blood flow of patients with diabetes mellitus.
**Methods:** The research used pre-experimental design with one-group pretest-posttest. Sampling technique using purposive sampling as many as 62 patients with diabetes mellitus. Electrical stimulation was done by attaching electrodes to left and right calf muscles for 20 minutes, with frequency 3 times a week for 2 weeks. Before and after electrical stimulation performed foot circulation examination by ankle brachial index technique. Data were analyzed using Wilcoxon signed rank test.
**Results:** The results showed that before the stimulation was obtained the mean ankle brachial index 0.82 mmHg and after stimulation it was 0.95 mmHg ($p = 0.000$). There was an effect of electrical stimulation in increasing foot blood flow. A calf muscle contraction during stimulation leads to increased leg blood flow through the addition of vascular endothelial growth factor and increased nitric oxide as a vasodilator of blood vessels. Electrical stimulation can be applied in increasing the blood flow of the foot, thus preventing the occurrence of diabetic foot ulcers.
**Conclusion:** Stimulation is one therapy that can be done to prevent poor foot circulation of patients with diabetes mellitus.

**Keywords:** electrical stimulation; foot circulation; diabetes mellitus

## INTRODUCTION

Diabetes mellitus (DM) has a broad impact on the lives of patients, mainly due to the occurrence of prolonged complications. This disease is mentioned as one of the main causes of chronic disease and causes loss of limbs around the world (Hingorani et al., 2016). International Diabetes Federation (IDF) says that the prevalence of DM in the world in 2015 reached 7.3 billion people and is predicted to increase again in 2040 to 9 billion people. Indonesia is currently the seventh largest DM patient in the world with a total of 10 million people and is predicted to rise in sixth place by 2040 with a total of 16.2 million people. Based on the results of Basic Health Research (Riskesdas, 2013), an increase in DM prevalence in Indonesia from 1.1% in 2007 to 2.1% in 2013.

High blood glucose levels in DM patients can cause increased blood viscosity resulting in thickening of the capillary membrane, which erythrocytes, platelets and leucocytes are attached to the blood vessels. Narrowing of blood vessels due to membrane thickening resulted in reduced blood flow, resulting in various complications in patients with DM (Association, 2017).

Peripheral neuropathy is the most common complication of type 2 DM and occurs in the lower extremity of the limb which may affect the sensory, motor, and autonomic systems. The risk of peripheral neuropathy disorders 2 to 4 times higher in diabetics compared with non-diabetics, this disorder will increase with age and duration of diabetes (Beckman, Creager, & Libby, 2002).

One of the symptoms that appear in diabetic neuropathy is a leg injury. This is due to the disruption of blood vessels in the peripheral arteries and is a factor that contributes to the development of wounds in diabetic feet up to 50% of cases. Recommended interventions to reduce the continued effects of peripheral blood flow disruption such as regular exercise routine (walking, leg exercising, joint movement range) (Francia et al., 2015). Prevention to reduce the bad feet circulation in patients with DM is often done today, among others, regular exercise such as gymnastics fitness, walking exercise, range of motion on the feet. Some DM patients are found not to have enough time to exercise regularly because they are busy with other activities.

Electrical stimulation is one alternative therapy that can improve foot circulation to prevent potential foot injuries. Several studies have shown that commonly used electrical stimulation is to reduce pain, speed up wound healing and lower blood sugar levels. Research on electrical stimulation combined with walking for 50 minutes a day, 3 times a week for 4 weeks found an increase in foot circulation of DM patients compared to walking without electrical stimulation (Park, Son, Kim, Kim, & Oh, 2011). Previous study on electrical stimulation for 60 minutes, 3 times a week for 4 weeks found the perfect wound healing in the diabetic foot (Asadi, Torkaman, Mohajeri-Tehrani, & Hedayati, 2015). Previous research about electrical stimulation for 40 minutes a day, 3 times a week for 2 weeks on quadriceps femoris muscle with 50 Hz frequency was obtained before the average electrical stimulation of blood sugar 197.30 mg/dl and after stimulation in the last session an average of 148.10 mg/dl (Sharma, Shenoy, & Singh, 2010). Foot circulation is assessed using the ankle brachial index (ABI) method, which compares the systolic ankle and brachial systolic values. The purpose of this study was to determine differences in foot circulation of patients with diabetes mellitus before and after electrical stimulation of the calf muscles.

## METHODS

*Study Design*
This study used one-group pretest-posttest pre-experimental design. The study was conducted at Public Health Center Muara Satu and Public Health Center Muara Dua of Kota Lhokseumawe Indonesia from 5 July to 10 September 2017.

*Sample*
The sample size was 62 DM patients, using purposive sampling technique. The inclusion criteria were (1) age over 40 years, (2) not diabetic foot ulcer, (3) blood sugar levels less than 500 mg/dl (4) did not suffer from respiratory diseases, (5) no cerebrovascular disorders. Exclusion criteria include DM patients with heart rhythm disturbances, experiencing respiratory complications (tachypnea/bradypnea).

*Intervention*
The electrical stimulation given in this study was using Veinoplus. Before the stimulation was conducted, blood glucose examination and the measurement of ankle brachial index (ABI) were done as a pretest to determine foot

circulation. Stimulation was done for 20 minutes by attaching electrodes to both left and right calf muscles in the sleeping patient position. Treatment was given 3 times a week for 2 weeks. In the last session of the treatment performed, blood sugar and ABI were measured again.

ABI was determined on the patient's supine position by inserting a sphygmomanometer cuff over the ankles (lateral malleolus), applying jelly to the artery tibial anterior, the vascular probe was placed in the artery tibial anterior of the until a pulse was heard, the cuff was then pumped until no pulse was heard. The cuff was released slowly to determine the ankle systolic. Similarly, to determine the brachial systolic in the patient's position to sleep on his back, then the cuff was mounted on the upper arm, the vascular probe was placed on the brachial artery. While blood glucose levels were assessed by taking blood samples on the patient's fingertips after being stabbed using a needle until blood came out about one drop, inserted into the Gluco-Dr.

*Instrument*

Instruments in this study included electrical stimulation with the brand VeinoPlus with battery type 9V (made in AD Rem Technology Paris, France). Vascular Doppler brand Bistos HI-dop (made in Model BT-200, 8 MHz ultrasound frequency, 1.5 V x 2 type battery (AA Type) (made in Bistos Co. Ltd., Seoul Korea). Furthermore, to support the implementation, vascular doppler, Sphygmomanometer Aneroid Type Tensi 200 brand OneMed (permit Depkes RI AKL 20501906481), was used to measure the systolic ankle and brachial pressure. Examination of blood glucose levels used Gluco-Dr (made in Alimedicus, Indonesia).

*Ethical Consideration*

This study has obtained ethical approval from the Ethics Committee of the Faculty of Nursing, University of Sumatera Utara Indonesia with number 1236/VII/SP/2017. The researcher also confirmed that each respondent has gained approval for the research.

*Data Analysis*

Data were analyzed using Wilcoxon signed rank test

## RESULTS

Table 1 shows that the mean age of patients in this study was 57.15 years (standard deviation = 6.44). The most dominant age was found by the 56-65 years old (62.90%). Minimum age 42 years, and maximum 72 years. The majority of gender was females (64.50%).

**Table 1** Characteristics of respondents

| No | Characteristics | f | % | Average | Min-Max |
|---|---|---|---|---|---|
| 1. | Age (years) | | | 57.15 | 42-72 |
| | 36 – 45 years old | 5 | 8.10 | | |
| | 46 – 55years old | 16 | 25.80 | | |
| | 56 – 65years old | 39 | 62.90 | | |
| | >65 years old | 2 | 3.20 | | |
| 2. | Gender | | | | |
| | Female | 40 | 64.50 | | |
| | Male | 22 | 35.50 | | |
| 3. | Body Mass Index (BMI) | | | 21.93 | 15.11-28.65 |
| | < 17 kg/m2 | 3 | 4.80 | | |
| | 17 – 18.5 kg/m$^2$) | 3 | 4.80 | | |
| | 18.6–25kg/m$^2$) | 48 | 77.40 | | |
| | 25.1–27kg/m$^2$) | 6 | 9.70 | | |
| | > 27 kg/m$^2$ | 2 | 3.20 | | |
| 4. | Suffered from DM | | | 9.63 | 2-22 |
| | < 10 years | 41 | 66.10 | | |
| | > 10 years | 21 | 33.90 | | |

The average of Body mass index (BMI) was 21.98 kg/m$^2$ (standard deviation 2.87), with the minimum BMI value of 15.11 kg/m$^2$ and maximum value of 28.65 kg/m$^2$. The average of patients suffered from DM was 9.63 years (standard deviation 5.05 years), with 66.10% less than 10 years and 33.9% more than 10 years. (66.10%).

Table 2 shows that, before stimulation, the patient's blood sugar levels were in mild and moderate range (38.70%) and ABI in the mix arterial-venous category (50%). Meanwhile, after the stimulation, the blood sugar levels were in the normal category (58.10%) and ABI increased or was in normal range (82.30%).

**Table 2** Frequency distribution Blood sugar levels and ankle brachial index values

| No | Blood Sugar Level and Ankle Brachial Index | Pre-test | | Post-test | |
|---|---|---|---|---|---|
| | | f | % | f | % |
| 1. | Blood Sugar Level | | | | |
| | Normal (<200 mg/dl) | 4 | 6.50 | 36 | 58.10 |
| | Mild (200-300 mg/dl) | 24 | 38.70 | 20 | 32.3 |
| | Moderate (301-400 mg/dl) | 24 | 38.70 | 6 | 9.70 |
| | Heavy (>400 mg/dl) | 10 | 16.10 | | |
| 2. | Ankle Brachial Index | | | | |
| | Mix arterial – venous | 31 | 50 | 2 | 3.20 |
| | Venous disorder | 16 | 25.80 | 9 | 14.50 |
| | Normal | 15 | 24.20 | 51 | 82.30 |

Differences in blood sugar level and ABI values before and after the Wilcoxon signed rank test were presented in Table 3. The results showed that there was a significant difference in the decrease in blood sugar levels (p = 0.000, p <0.05). There was also a significant difference in ABI before and after the treatment (p = 0.000, p <0.05).

**Table 3** Differences in blood sugar levels and brachial ankle value index between pre-test and post-test of electrical stimulation

| No | Blood Sugar Level and Ankle Brachial Index | Pre-test | Post-test | p-value |
|---|---|---|---|---|
| 1. | Blood Sugar Level | | | |
| | Mean | 305.06 | 204.87 | 0.000 |
| | Standard of deviation | 86.97 | 68.30 | |
| | Min – Max | 114 - 425 | 90 - 375 | |
| 2. | Ankle Brachial Index | | | |
| | Mean | 0.82 | 0.95 | 0.000 |
| | Standard of deviation | 0.11 | 0.79 | |
| | Min – Max | 0.62 – 1.17 | 0.77 – 1.17 | |

## DISCUSSION

### Blood Sugar Level Pre-test and Post-Test Electrical Stimulation

Increased blood sugar levels in DM patients due to pancreas do not produce enough insulin, or when the body cannot effectively use the insulin that has been produced (WHO, 2016). Hyperglycemia can cause increased blood viscosity which leads to poor blood. Changes in blood sugar levels are influenced by multifactor, including age, body mass index, long DM, physical activity and tobacco use (Pamungkas, Limansyah, Sudarman, & Siokal, 2016).

Based on table 1 above, it can be seen that there was a decrease in blood glucose levels before and after electrical stimulation. The average of pre-test blood sugar levels were 305.06 mg/dl and post-test 204.87 mg/dl (p = 0.000). Decreased blood sugar levels can occur due to muscle contraction by vibration of electrical stimulation in the calf muscles. Cells take glucose in the blood to convert into energy within the mitochondria. Furthermore, such energy causes contraction in the smooth muscles in the calf. A significant reduction in the study was also influenced by patient compliance in regular blood sugar control and oral therapy to lower blood sugar.

According to Asadi, Torkaman, Mohajeri-Tehrani, and Hedayati, it is explained that the management of blood glucose levels of DM patients can be pursued by doing physical exercises so that the glucose needs will be increased compared to the condition at rest. Regular electrical stimulation increases the absorption of glucose by the tissues during and after exercise, improves insulin sensitivity and improves the translocation of glucose transport. In addition to the stimulation provided, DM management also depends on lifestyle, pharmacological interventions with oral hypoglycemic or insulin preparations, blood glucose monitoring and early or continuous health education or counseling (Asadi et al., 2015).

The absorption of glucose that is transferred by muscle contraction is responsible for the decrease in blood glucose levels. Electrical stimulation can activate the absorption of glucose in the calf muscles by transporting GLUT-4 to the cell surface. However, the decrease in blood glucose after 2 weeks of stimulation in this study may be due to the accumulation of insulin-dependent effects of increased insulin sensitivity.

**Differences in Foot Circulation Pre-test and Post-Test of Electrical Stimulation**

Increased age in DM patients can cause endothelial vascular disorders. This disorder occurs from the early age of the elderly, causing the shrinkage of skeletal muscle cells progressively causing the disorder of protein synthesis.

The adverse effects of circulation will damage the nerves. When interference on the autonomic nerves it will experience impaired function in the smooth muscles, glands and visceral organs. Changes in muscle tone can cause blood flow abnormalities (Petrofsky, 2011).

From the research results, it is found that there was a difference of foot circulation before and after electrical stimulation. The average of ABI before the intervention was 0.82 (venous disorder) and after the intervention was 0.95. There was an increase in the ABI value by an average of 0.13 or included in the normal ABI category. The result of test analysis of Wilcoxon signed rank test revealed that 82.5% of respondents increased the circulation. The electrical stimulation has a significant effect on increasing the foot circulation of DM patients. These results were consistent with the findings of previous study stated that the stimulation made a change in peripheral skin temperature caused by increased blood flow (Asadi et al., 2015). Aldayel, Jubeau, Mcguigan, dan Nosaka reported that skin temperature in healthy individuals increased significantly within 10 minutes after induction of electrical stimulation in the quadriceps femoris muscle compared with the control group (Aldayel, Jubeau, McGuigan, & Nosaka, 2010). While Sandberg, Sandberg, and Dahl revealed that induction of electrical stimulation of trapezius muscle in healthy individuals for 15 minutes can improve blood circulation in muscles (Sandberg, Sandberg, & Dahl, 2007).

Stimulation of the calf muscles causes increased blood flow in the leg area through the addition of endogenous blood vessel factors, which in turn will reduce the pain experienced by diabetic patients. Thakral et al. states that increased perfusion due to electrical stimulation is associated with increased vascular endothelial growth factor (VEGF) (Thakral et al., 2013). Where, VEGF is an angiogenic factor with selective endogenous cell mitogenic activity that plays an important role in vasculogenesis, the growth factor is highly specific to the function of vascular endothelial cells. The role of VEGF is very dominant in the process of formation of new blood vessels called angiogenesis. In addition, VEGF also plays a role in the permeability of blood vessels that cause extravasion of several other molecules. VEGF determination after electrical stimulation occurs through RNA expression by oxygen exposure initiated by contraction of the smooth muscles that cause angiogenic formation of blood vessels. Angiogenic itself is a basic process in the formation of new blood vessels from the existing blood vessels. The angiogenic target here is arterial or venous capillaries in vascular endothelial cells and smooth muscle cells (Valiatti et al., 2011).

Asadi et al. increased blood flow in the wound area was associated with a vasodilation process caused by electrical stimulation. By releasing nitric oxide (NO), as a coronary vasodilator, or inhibiting sympathetic vasoconstriction. NO is a small atom, relatively unstable, free radicals and lipophilic molecules. NO works as an intermediary or regulates endothelium-dependent vasorelaxation, blood pressure, macrophage cytotoxicity, platelet aggregation. In addition, the role of NO serves to dilate blood vessels, phagocytosis process and inhibit platelet adhesion (Asadi et al., 2015).

The mechanism of improving blood circulation during electrical stimulation is due to the production of NO in vascular endothelial cells in response to electrical stimulation. A calcium channel is called a transient receptor voltage vanilloid (TRPV) -4 that contains an open voltage to respond to electrical stimulation in the tissues. It further increases blood flow to the tissues through ENOS which is activated with calcium (Petrofsky, 2011). Ghosh, Sherpa, Bhutia, Pal, dan Dahal explains that increased superoxide concentration causes decreased endothelial nitric oxide synthase (eNOS) isoforms by triggering the final product of glycation and polymerization. NO is synthesized as a byproduct of the conversion of its L-arginine physiological precursor to L-citrulline. This reaction is catalyzed by an enzyme known as NO synthesis (NOS) (Ghosh, Sherpa, Yazum Bhutia, & Dahal, 2011).

Toda, Imamura, dan Okamura stated that NO is constitutively produced from endothelial cells and nerve fibers that contribute to the regulation of cardiovascular function (Toda & Morimoto, 2008). This substance is formed through endothelial NO synthesis that induces vasodilation, increased blood flow rate, thrombocyte aggregation and adhesion resistance, decreased smooth muscle proliferation and as other antioxidants. When a person has hypercholesterolemia, hyperglycemia and hypertension can cause endothelial cell disruption resulting in disruption of the NO release. In people who stimulated an electric current in a low-voltage category, it can cause NO release of vascular endothelial cells, which can lead to vasodilation associated with increased blood flow to tissues and the metabolism of glucose present in the blood.

The results showed that, after electrical stimulation performed on the calf muscles for 20 minutes with frequency 3 times a week for 2 weeks, there was an increase in circulation to the foot area. Significant increases in ABI after electrical stimulation are important to suggest that the form of passive exercise therapy has a therapeutic effect on diabetes mellitus.

Limitations of the study include that there was no examination of nitric oxide levels to detect vascular endothelial changes that cause vasodilation of blood vessels, so it might limit the results of the study, especially in the levels of NO.

## CONCLUSION

There was an effect of electrical stimulation on the improvement of foot circulation of patients with DM. Stimulation is one therapy that can be done to prevent bad foot circulation resulting from high levels of sugar in the blood so it can be used as management or prevention diabetic feet in diabetic patients. Health workers, especially nurses, need to socialize the use of electrical stimulation to improve foot circulation or reduce pain in diabetes mellitus.

**Declaration of Conflicting Interest**
None declared.

**Funding**
This study has been supported by Faculty of Nursing, University of Sumatera Utara, Medan, Indonesia.

**Author Contribution**
All authors contributed equally in this study.

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**Cite this article as:** Iskandar., Dharmajaya, R., Ariani, Y. (2018). Increasing foot circulation with electrical stimulation in patients with diabetes mellitus. *Belitung Nursing Journal,4*(3), 343-349. https://doi.org/10.33546/bnj.414