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THE EFFECT OF DIABETIC FOOT EXERCISES ON SENSITIVITY AND DEFORMITIES (MOTOR) OF THE FEET IN PATIENTS WITH TYPE 2 DIABETES MELLITUS WITH NEUROPATHY COMPLICATIONS

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ABSTRACT

Neuropathy is a common chronic complication in people with diabetes. Neuropathy refers to diseases that affect various types of nerves, including sensory, motor, and autonomic nerves. Diminished foot sensitivity and structural abnormalities may impede the patient's ability to perceive foot injuries, increasing the risk of more serious complications. Foot exercise is an effective method for people with diabetes mellitus to prevent injury and improve blood circulation in the feet. It improves blood circulation, strengthens the small muscles of the foot, and prevents foot deformities. This study aimed to determine the effect of diabetic foot exercises on foot sensitivity and motor deformity in type 2 diabetes mellitus patients with neuropathy. Method:This study employed a quantitative method with a one-group pre-test and post-test design. The sampling technique used purposive sampling with 35 respondents based on the inclusion and exclusion criteria. The data were collected through interviews and assessment of sensitivity and foot deformity. Sensitivity was measured using a 10-gram Monofilament Test, while foot deformities were evaluated with a deformity observation sheet. The statistical analysis test revealed that right foot sensitivity obtained a p-value = 0.001 (<0.05) and left foot sensitivity had a p-value = 0.013 (<0.05). The foot deformity signified p-value = 1.000 (>0.05). Diabetic foot exercise has a significant effect on foot sensitivity. However, it did not reveal a significant impact on motor foot deformity in type 2 diabetes mellitus patients with neuropathy complications in the Working Area of Puskesmas Gambirsari Surakarta.

Keywords: deformity; foot exercises; gymnastics; neuropathy sensitivity; type 2 diabetes mellitus

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INTRODUCTION

Diabetes Mellitus (DM) is a metabolic disorder characterized by an increase in blood sugar levels due to impaired insulin secretion and the effect of insulin action (ADA, 2021).The number of people with DM is estimated to increase by approximately 111.2 million, with this number expected to continue rising to reach 700 million by 2045. According to the International Diabetes Federation (IDF) in 2019, China had 116.4 million cases, India around 77 million cases, and the United States with 31 million cases, making these three countries the ones with the highest number of DM patients in the world. The World Health Organization (WHO) estimated that in Indonesia, the incidence of DM would increase to 21.3 million people (WHO, 2021). Modern lifestyle changes are one of the factors contributing to diabetes mellitus (DM). Approximately 4.2 million people die each year between the ages of 20 and 79 due to DM (Coregliano-Ring *et al*., 2022). Indonesia ranks 5th with a population of 179.72

million people, with a prevalence of 10.6%. In Indonesia, 60-70% of DM patients are aged 45 years and older. In Central Java Province, DM cases reach 37.57%. In Surakarta City, there are 159,892 DM patients, with the number in Banjarsari District reaching 40% (Rikesdas, 2018).In Surakarta, there were 12,105 cases of type 2 DM in 2021, an increase compared to 2020, which had 8,884 cases (Dinas Kesehatan Kota Surakarta, 2021).

Diabetes patients need to undergo regular and consistent treatment to support diabetes recovery. Those who do not regularly follow their treatment regimen may experience vascular complications. These DM complications are divided into two categories: macrovascular complications (such as coronary heart disease, stroke) and microvascular complications (such as retinopathy, nephropathy, and neuropathy). The incidence of diabetic neuropathy complications remains high, affecting 60%-70% of patients with type 1 and type 2 DM. The prevalence of diabetic peripheral neuropathy complications in Malaysia is 54.3%, the Philippines 58.0%, and Indonesia 50.0% among patients with type 1 and type 2 DM (Simamora et al., 2020). Generally, diabetes patients often do not recognize neuropathy, assuming it to be a common condition resulting from complications of other diseases (WHO, 2021).

Neuropathy refers to a disease that affects all types of nerves, such as sensory, motor, and autonomic nerves, most commonly occurring in the peripheral parts of the body and also known as Diabetic Peripheral Neuropathy (DPN) (Pfannkuche *et al*., 2020). DM patients suffering from neuropathy may experience sensory disturbances, leading to loss of sensation or numbness, which is often unnoticed by diabetes patients. Motor disturbances result in muscle wasting (atrophy), foot deformities, biomechanical changes in the feet, and pressure distribution that can lead to ulcers. Autonomic disturbances cause reduced sweating on the feet, making the skin dry, prone to fissures, and calluses (Mildawati *et al*., 2019).

Management to prevent the occurrence of neuropathy complications includes exercise. The type of exercise recommended by the American Diabetes Association (ADA) is foot exercises. These foot exercises are highly suitable as they can improve the degree of peripheral neuropathy. Foot exercises are easy to perform, can be done anytime and anywhere, do not require much time, and do not involve many movements or actions that could worsen the degree of neuropathy in diabetes mellitus (DM) patients (Simamora *et al*., 2020).

Foot exercises are a form of aerobic activity that includes variations in leg movements that meet the criteria of being continuous, rhythmic, interval-based, progressive, and endurance-focused, requiring these phases to be incorporated. Foot exercises for diabetic patients can help improve blood circulation, strengthen foot muscles, and increase insulin production, which is used to transport glucose into cells, thereby helping to lower blood sugar levels (Megawati *et al*., 2020). The recommended frequency for foot exercises for DM patients with neuropathy is three times a week, with a duration of 20-30 minutes (Sanjaya *et al*., 2019).
The general objective of this study is to analyze the effects of diabetic foot exercises on sensitivity and deformities (motor) of the feet. The specific objectives of this study include understanding the characteristics of DM patients, including age, gender, duration of illness, occupation, and education. Additionally, the study aims to identify pre-test and post-test scores to assess the differences in sensitivity and foot deformities during foot exercises. Finally, it aims to determine the impact of diabetic foot exercises on sensitivity and foot deformities (motor) in patients with type 2 DM and neuropathy complications.

METHOD

This study uses a quantitative method with a one-group pre-test and post-test design. The sampling technique used is purposive sampling. The number of respondents in this study is 35, selected based on inclusion and exclusion criteria. The inclusion criteria for this study are DM patients who show signs and symptoms of neuropathy, such as cramps, numbness, tingling, reduced foot sensitivity, joint stiffness, and decreased muscle strength. The exclusion criteria are DM patients with diabetic wounds such as ulcers, gangrene, and amputations, as well as DM patients in a weakened or critical condition. The study was conducted from March 6 to March 31, 2024, in the working area of the Gambirsari Community Health Center, Surakarta. Foot sensitivity in this study was measured using the 10g Monofilament Test. Foot motor deformities were assessed using the Michigan Neuropathy Screening Instrument (MNSI) observation sheet, which has been validated and tested for reliability by Sutkowska et al. (2023). The tools and materials used in this study included chairs, newspapers, a 10g monofilament, foot deformity observation sheets, foot sensitivity observation sheets, and foot exercise pamphlets. Foot exercises were conducted three times a week for two weeks. In this study, ethical testing has been conducted and approved at Dr. Moewardi General Hospital, with the number 585/II/HREC/2024. Data analysis in this study was performed using the Wilcoxon Rank Test with a p-value <0.05.

RESULT

Table 1.
Respondent characteristics (n= 35)

Characteristic	f	%
Elementary School	20	57,1
Junior High School	9	25,7
Senior High School	6	17,1
Occupation		
Housewife	17	48,6
Private Employees	5	14,3
Not employed	3	8,6
Self-employed	10	28,5
Duration of DM		
< 1 Year	0	0
2 - 5 Year	25	71,4
> 5 Year	10	28,6
Gender		
Male	13	37,1
Female	22	62,9
Age		
26 - 35	0	0
36 – 45	4	11,4
46 – 55	11	31,4
56 – 65	12	34,3
> 65	8	22,9

Table 2.
Sensitivity Level Before and After performing diabetic foot exercises (n = 35)

Pretest		Postest	
f	%	f	%
0	0	15	42,9 %
17	48,6 %	15	42,9 %
18	51,4 %	5	14,3 %

Table 3.
Sensitivity Level Before and After performing diabetic foot exercises (n=35)

Variabel	Z	P value	
Right Foot Sensitivity	-4,460	0,001	Ho- rejected
Left Foot Sensitivity	-2, 496	0,013	Ho- rejected

DISCUSSION

Respondent Characteristics

Based on Table, it was found that the number of female respondents is greater than that of male respondents, with a total of 22 female respondents (62.9%). This aligns with the study by Rahmawai (2021), which found that women tend to have a higher risk of developing type 2 diabetes. This is due to women having higher cholesterol levels compared to men and differences in lifestyle and activities that affect daily life. Women are at higher risk of developing type 2 diabetes than men. According to the analysis, women are at higher risk for diabetes because they are physically more likely to experience an increase in body mass index. Prolonged menstrual cycle syndrome (premenstrual syndrome) lasting 40 days or more or irregular menstrual cycles is at risk for type 2 diabetes. Irregular menstrual cycles and type 2 diabetes have risks similar to obesity, hyperinsulinemia, and more centralized fat distribution. Obesity is associated with increased conversion of androgens to estrogens in peripheral adipose tissue. This is a major factor in the development of type 2 diabetes, which is related to infertility and menstrual disorders. Additionally, postmenopausal women have a higher incidence of type 2 diabetes than premenopausal women. Total protein is a major risk factor for premenopausal women with diabetes (Li *et al*., 2019).. The researcher assumes that the female gender tends to be at risk of experiencing diabetes mellitus related to body mass index, especially during menopause, which leads to easy fat accumulation, hindering glucose transport into cells.

The majority of respondents were aged 61-70 years, with a total of 13 respondents (37.1%). This is consistent with the study by Purwandari (2022), which explains that the risk factors for type 2 diabetes that cannot be changed include age, preferences, ethnicity, family history, and medical history. Age is closely related to the physiology of aging. As age increases, bodily functions decline, and insulin hormone cannot function optimally, leading to high blood sugar levels. Type 2 diabetes often occurs in individuals over 40 years old due to a lack of exercise in this age group, decreased muscle mass, and weight gain. Patients over 40 years old have a higher risk because the aging process in this age group leads to changes in body composition, causing damage to pancreatic beta cells, target tissue, nerve systems, and other hormones that can affect glucose levels glukosa (Vadila *et al*., 2021). Another related study by Widiasari (2021) explains that the age range of 61-70 years is more likely to develop diabetes mellitus because, at this age, there is a decline in organ function. The researcher assumes that older age significantly increases the risk of diabetes mellitus, especially regarding sensitivity and motor impairment in the feet.

Respondents had a primary school education, with a total of 20 respondents (57.1%). A person's education level also affects the incidence of diabetes. The level of education can influence an individual's ability and knowledge in applying healthy behaviors in daily life, particularly in diabetes prevention. The higher a person's education level, the greater the likelihood of maintaining a healthy lifestyle. The high prevalence of hyperglycemia among respondents with low levels of knowledge indicates that a lack of awareness of this disease results in uncontrolled glycemia (Hasneli, 2019). This contrasts with the study by Ramadhani (2023), which argues that a person with a higher education level is expected to have broader

knowledge. However, this is not absolute, as someone with a lower educational background may not necessarily have low knowledge. Knowledge can come from non-formal sources and does not have to originate from formal education (Ramadhani & Khotami, 2023).

The longest duration of suffering from type 2 diabetes was 4-7 years, with a total of 19 respondents (54.3%). This is consistent with the study by Purwandari (2022), which states that the incidence of peripheral neuropathy averages around 5 years of disease duration; hence, the duration of the disease can influence the emergence of neuropathic complications, which increases the longer one suffers from the disease. Diabetes has a higher risk of complications. In line with this research, it is observed that the longest suffering experienced by respondents is between 4 to 7 years or more than 5 years, which aligns with the theoretical perspective that long-term complications arising from type 2 diabetes do not occur within the first 5 to 10 years. Due to varying sensitivity and deformities of the feet after performing foot exercises, it indicates that respondents do not yet experience dangerous long-term complications related to neuropathy.

Respondents were housewives, with a total of 17 respondents (48.6%). This is consistent with the theory by Arania (2021), which states that individuals with light daily physical activity have a higher risk of developing type 2 diabetes compared to those with intensive jobs. This is because housewives only manage household chores and light daily tasks. Occupational factors influence the risk of diabetes mellitus (DM); jobs with light physical activity lead to insufficient energy expenditure by the body, causing excess energy to be stored as fat, resulting in obesity, which is a risk factor for diabetes mellitus (Arania *et al*., 2021).

Sensitivity Level Before and After performing diabetic foot exercises

Pre-test results show that the majority of right foot sensitivity among respondents before performing diabetic foot exercises fell into the severe sensitivity category, with 18 respondents, while the left foot sensitivity fell into the mild sensitivity category, with 25 respondents. Damage to sensory nerve cells in the feet causes a reduction in the nerves functioning as protective sensation. Loss of protective sensation increases the likelihood of diabetic patients developing diabetic ulcers. Blood circulation is the flow of blood pumped by the heart through blood vessels, which is then distributed throughout the body, including the feet (Rahayu et al., 2021). Foot sensitivity is the damage to sensory nerve cells in the soles of the feet affected by nerves, causing complications referred to as neuropathy. Increased reactivity of the lower extremities will lead to heightened aggression of red blood cells, hindering blood circulation and resulting in foot sensitivity issues in diabetes mellitus patients (Siska Pindi Triani *et al*., 2022).

Post-test results show that the majority of right foot sensitivity among respondents after being given diabetic foot exercises falls into the good sensitivity category, with 15 respondents, and the left foot sensitivity category contains 22 respondents. According to theory, physical activity (exercise) plays a vital role in controlling blood sugar levels in diabetes mellitus patients. During physical exercise, there is an increase in glucose utilization by active muscles, which can directly lead to a decrease in glucose levels. Additionally, physical activity benefits include improved sensitivity, weight loss, and enhanced insulin sensitivity (Alza *et al*., 2020). The physical exercise performed relaxes the body and improves blood circulation. Improved blood circulation through exercise stimulates blood to deliver more oxygen and nutrients to body cells (Megawati *et al*., 2020).

In the pre-test, it was found that the level of foot deformities in the right foot before diabetic foot exercises was categorized as severe deformity, with a total of 32 respondents, while the left foot also had severe deformity, with 29 respondents. Foot deformities are one of the factors that can lead to diabetic ulcers. Diabetic neuropathy is the most common complication of chronic diabetes that can result in diabetic ulcers. Common foot deformities such as hallux valgus (HV) and hammertoes can lead to bone bumps that cause ulcers on the top or back of the toes due to the thin skin and subcutaneous tissue. The impact of diabetic foot on blood vessels can lead to muscle function impairment and loss of bone density, as well as biomechanical foot disorders and the occurrence of foot ulcers (Luo *et al*., 2023).

Post-test results indicate that after performing diabetic foot exercises, there was no decrease in the deformity of the right foot among the 32 respondents and the deformity level of the left foot among the 29 respondents. Foot deformities are a complication of long-term diabetes mellitus, particularly occurring after the onset of neuropathy and decreased circulation to the periphery. Patients who have suffered from diabetes for a longer duration are at a greater risk of developing foot deformities (Adebabay *et al*., 2023). Diabetic neuropathy leads to atrophy of the small muscles in the feet, resulting in a loss of supportive surface and an increase in bone protrusions. These changes are believed to cause higher plantar pressure in the midfoot and forefoot compared to patients with diabetes mellitus without neuropathic complications (Luo *et al*., 2023). The researcher's analysis indicates that there is no increase in the level of deformities because the mechanical process of foot deformity formation requires a relatively long time, starting with intrinsic muscle weakness that causes an imbalance in toe movements. Over time, a person's body weight will change, indicating that physical exercise alone is insufficient to address foot deformities.

Analysis of the effect of diabetic foot exercises on foot sensitivity before and after performing diabetic foot exercises

Based on Table, the results of the Wilcoxon Sign Rank Test show that the sensitivity of the right foot has a p-value of $0.001 < \alpha = 0.05$, and the sensitivity of the left foot has a p-value of $0.013 < \alpha = 0.05$. Thus, Ha is accepted and Ho is rejected, indicating a significant effect of diabetic foot exercises on foot sensitivity in patients with DM and neuropathic complications. This aligns with the study by Megawati et al. (2020), which explains that diabetic foot exercises positively affect foot conditions, where cold extremities become warmer, stiff feet become flexible, numb feet regain sensation, and atrophied feet gradually return to normal. In statistical tests, it was found that foot exercises help improve the small muscles in the feet of patients with neuropathy. Diabetic foot exercises are also very easy to perform (they can be done indoors or outdoors).

Foot exercises can stimulate movement, stretch the muscles of the feet, and compress the blood vessels around those muscles. This encourages blood flow back to the heart, thereby lowering venous pressure. This mechanism is referred to as the "venous pump." This mechanism enhances blood circulation in the feet, strengthens the muscles of the feet, prevents deformities, increases the strength of the calf and thigh muscles, and helps address joint limitations (Qurotulnguyun *et al*., 2023). In research by Wahyuni (2019), it is explained that diabetic foot exercises are an appropriate physical activity to improve circulation, especially in the feet compared to other physical activities. The recommended exercises for DM patients are aerobic, which require oxygen and can help with blood circulation, strengthen the small muscles in the feet, prevent foot deformities, and can enhance the potential for diabetic ulcers on the feet while increasing insulin production used in glucose transport to cells, thereby helping to lower blood glucose levels (Rahmasari & Wahyuni,

2019).

The researcher concludes that diabetic foot exercises have many benefits, one of which is to increase foot sensitivity in patients with type 2 DM. This is because, during diabetic foot exercises, the muscles of the feet are estimated to experience an increase in blood flow three times that of resting muscles. The physiological effects of regular diabetic foot exercises will achieve a direct mechanical effect from the muscles or tissues where the exercises can stimulate blood circulation, making the muscles softer and more flexible. This undoubtedly facilitates peripheral blood circulation in the feet, leading to increased foot sensitivity. The physical activity of foot exercises can also be integrated into daily activities since they do not require special equipment and can be performed anytime and anywhere. If done regularly three times a week for 25-30 minutes and performed correctly, it will improve foot sensitivity in patients with diabetes mellitus.

Analysis of The Effect Of Diabetic Foot Exercises on Foot Deformity Before And After Performing Diabetic Foot Exercises

Based on Table, the results of the Wilcoxon Sign Rank Test show that the deformities of the right and left feet have a p-value of $1.000 > \alpha = 0.05$, leading to the rejection of Ha and acceptance of Ho, which means that there is no significant effect of diabetic foot exercises on foot (motor) deformities in patients with type 2 DM and neuropathic complications. The average deformities in the respondents' feet were characterized by overlapping toes, hallux valgus, hammer toes, and calluses on the soles of the feet. The results of this study are consistent with the statement by Susanti & Amita, (2021)that foot deformities commonly occur in DM patients and are often associated with ulcers, including hallux rigidus, hallux valgus, hammer toe, claw toe, and prominent metatarsal head. The mechanisms leading to foot shape abnormalities in DM patients are not well understood; however, several theories state that foot deformities occur due to weakness in leg muscles and lack of joint movement. Motor neuropathy is believed to weaken intrinsic muscles, disrupting the balance of movement between flexion and extension of the toes. Atrophy of small muscles in the feet causes toe deformities leading to hammer toes, claw toes, and prominent metatarsal heads, while areas of the foot with deformities experience high pressure, resulting in calluses (Luo et al., 2023).

A study by Adebabay (2023) shows that poor glycemic control is a major risk factor for foot deformities. It has been proven that poor glycemic control can increase the occurrence of Charcot foot deformities sixfold compared to patients with good glycemic control. Poor glycemic control can lead to persistent hyperglycemia affecting the entire body system, including muscles and joints. Structural changes occur in the tendons and capsules of DM patients due to long-term hyperglycemic conditions, resulting in stiffness and joint weakness. Neuropathy is associated with foot deformities, and neuropathy is not a significant factor in the development of hallux valgus. Increased pressure and plantar load on diabetic patients with hallux valgus may be caused by larger ulcer sizes, while increased ulcer size also raises the risk of infection (Adebabay *et al*., 2023). Previous research has shown that motor neuropathy can lead to muscle weakness, causing deformities and reducing the range of dorsiflexion at the ankle related to the severity of metatarsophalangeal joint deformities.

Based on the results of this research and the theories presented, the researcher concludes that the reason there were no changes in foot deformities after performing diabetic foot exercises is that foot deformities take a very long time to develop, starting from the weakness of intrinsic muscles, which leads to imbalanced toe movements. Over time, as human body

weight increases, it causes uneven pressure distribution on the feet, resulting in changes such as flat feet, hammer toes, overlapping toes, hallux valgus, prominent metatarsal heads, and calluses. Based on this process, interventions to reduce foot deformities require a relatively long time. Therefore, providing diabetic foot exercises over a two-week period is considered insufficient to significantly improve foot deformities in diabetes patients.

CONCLUSION

Based on the research conducted, it is concluded that diabetic foot exercises have an effect on foot sensitivity levels but do not have a significant effect on foot deformities (motor) in patients with type 2 diabetes mellitus with neuropathic complications in the working area of the Gambirsari Health Center in Surakarta.

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