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Research on the Feet of Men with Diabetes as a Basis for Designing Shoes and Insoles

Bui Van Huan*, Le Khanh Trang
Hanoi University of Science and Technology, Ha Noi, Vietnam
**Corresponding author email: huan.buivan@hust.edu.vn*

Abstract

Diabetes is a dangerous chronic disease and often causes foot complications. Foot ulcers are a dangerous complication in patients with diabetes and lead to the risk of amputation. Shoes for diabetic patients play an important role in reducing the risk of foot ulcers. Therefore, diabetic patients need to use their own footwear, designed on the basis of anthropometric research and assessment of their foot complications. The article presents the method and results of measuring the feet and evaluating thier complications of 332 male diabetic patients over the age of 40. The patients' feet were measured at Khoai Chau district medical center, Hung Yen province and at National Hospital of Endocrinology. The results showed that diabetic foot complications in men with diabetes tend to get worse over time of illness. Foot complications/pathologies are the cause of differences in measurements of height, width and circumference of male diabetic foot. This difference was independent of the patient's age. According to foot complications, about 97.2% of male patients need to use "Extra Depth Diabetic Shoes"; 21.8% of patients required "Custom Molded Inlays/insoles"; and 3.2% of patients required "Custom Molded Diabetic Shoes" and "Custom Molded Inlays".

Keywords: Diabetes, men with diabetes, custom shoes/isnoles.

1. Introduction

Diabetic patients often suffer from dangerous complications such as coronary artery disease, cardiovascular disease, neuropathy, kidney failure, blindness... The feet of people with diabetes are easily damaged, because the patient has reduced or lost sensation, poor blood circulation... Common complications in the feet of people with diabetes are dry skin, peeling or cracking, calluses, deformities, impaired/loss of protective sensation (peripheral neuropathy) and ulceration [1, 2]. Foot lesions, especially ulcers, are very difficult to heal due to lack of oxygen and nutrients, reduced antibodies, etc., and lead to a high risk of amputation. Many studies show that over 25% of diabetic patients have foot-related problems, and the risk of amputation in diabetic patients is 15 - 46 times higher than that of people without the disease [3,4].

Diabetes is a chronic disease that cannot be cured. The number of diabetic patients is increasing rapidly, especially in Vietnam [1, 5]. According to research results in 2020 of the National Hospital of Endocrinology [6], in Vietnam, the rate of diabetes for people aged 30 - 69 years is 7.3%, the rate of pre-diabetes is 17.8 %. Hanoi and Ho Chi Minh cities have the highest rates of diabetes and pre-diabetes, about 8.3% and 22.3%, respectively. In Vietnam, the rate of undiagnosed diabetes is 62.6%. It is predicted that by 2025, there will be about 8.7% or about 4.2 million people aged 30 - 69 with diabetes [6]. According to information on the Ministry of Health's web portal, the annual rate of new foot ulcers is about 2% of the total number of patients. This rate increases from 5-7.5% in patients with peripheral neuropathy. Up to 15% of people with diabetes will develop foot ulcers, and about 60% of amputations are preceded by infected ulcers. The 5-year mortality rate of patients with lower limb amputation is 50-60% [7].

Therapeutic shoes play an important role in reducing foot ulcers in diabetic patients. This has been proven by many studies around the world [8]. So they have been researched, designed and produced in many countries. Two types of shoes are commonly used for diabetic feet: "Custom Molded Diabetic Shoes" made to fit the patient's foot; and mass-produced "Extra Depth Diabetic Shoes". In some countries, diabetic patients receive therapeutic shoes according to a doctor's prescription and are paid for by insurance [9]. For example, since 1993, the US Medicare Program has covered shoes, inlays (insoles) and accessories for diabetic patients [9]. According to this program, depending on the foot disease of diabetic patients or the risk of foot ulcers, the doctor will prescribe the type of therapeutic shoes/shoe insoles that the patient needs

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to use within 1 year. As follows:

1) Patients whose feet do not lose sensation, do not have deformities or a history of foot ulcers receive a pair of "Extra Depth Diabetic Shoes" and three pairs of "Diabetic Inlays" (A5500);

2) Patients with a loss of protective sensation in the foot, no deformity/slight deformity in the foot or a history of plantar ulceration receive one pair of "Extra Depth Diabetic Shoes" and three pairs of “Custom Molded Inlays” (A5512);

3) Patients whose feet have lost protective sensation plus deformity, or have a history of ulceration or plantar amputation receive a pair of “Custom Molded Diabetic Shoes” and two pairs of “Custom Molded Inlays” (A5513).

Therapy shoes and custom shoes for diabetics are made according to their foot anthropometric characteristics and shoe requirements. Foot studies of diabetic patients concluded that there was no difference in the parameters of their right foot and left foot [10-13]. Several studies have compared diabetic foot parameters with those of healthy human feet. Their results found that: 1) the foot length of diabetic patients did not differ from that of healthy subjects [11-13], or was longer than 3 mm [10]; 2) their width parameters are wider [10, 12-14] or equal [11]; 3) their foot circumference is larger than that of a healthy person's foot [10-13]. This difference depends on age group, sex, and body mass index [15].

Research on foot anthropometry of diabetic patients with the aim of designing and supplying footwear for them is quite new in Vietnam. In Vietnam, there are no therapeutic shoes or customized shoes for diabetics. Recently, there have been some anthropometric studies of female diabetic feet [12, 13, 16]. For male diabetic patients, there has been a publication on the establishment of a foot size system to design shoe lasts, design mass-produced “Extra Depth Diabetic Shoes" for patients [17]. The study focused on measuring the feet of patients with mild complications and no deformity at a medical location. This study has established a foot size system that includes 5 sizes by length (231.5 mm, 238 mm, 244.5 mm, 251 mm and 257.5 mm). Each size by length has 3 sizes by width [17]. However, there is still a lack of in-depth research on assessing foot damage, especially diabetic feet in men. They are the basis for designing and manufacturing shoes/insoles for patients. Meanwhile, the development of material technology, 3D printing technology... is a very favorable basis to be able to manufacture customized diabetic shoes/insoles at reasonable prices [18]. In this study, we focused on studying foot measurements and assessing foot damage/pathology in men with diabetes to serve as a basis for designing shoes and insoles for patients. The subjects studied were male diabetics with different levels of foot complications or risk of foot ulcers, from mild complications (as in published research [17]) to very serious complications. Besides taking foot measurements, we are more interested in the pathological characteristics of the foot or the level of foot damage. This is the basis for determining the type of shoe the patient needs to use according to the American classification [9]. Patients' feet are measured and evaluated at 2 medical locations: 1) At the local medical center, where people with mild diabetes are examined and receive medication. Their feet have not been damaged or have only mild complication; 2) At a central hospital, where diabetic patients with serious illnesses are regularly examined and treated. Foot complications, especially foot deformities, have an impact on their measurements. Statistics and analysis of foot complications in male diabetic patients are the basis for determining the type of shoes/shoe insoles that need to be designed and manufactured to suit their foot complications [9].

2. Research Objects and Methods

2.1. Research Objects

The study subjects were men with diabetes over 40 years old with varying degrees of foot complications. To ensure the representativeness and reliability of the measurement results, the number of feet to be studied is calculated according to the formula [13, 19]:

$$m = \frac{t\sigma}{\sqrt{n}} \Rightarrow n = \frac{t^2\sigma^2}{m^2}, \quad (1)$$

where: n is the set of samples to be determined; t is a probability; with p = 0.95, t = 1.96; m is the error of the set, m = 1, 2, 3, 4, 5... mm; σ is the standard deviation of foot length, mm.

The results of measuring the feet of 30 male patients received a σ value of 9.3 mm. According to formula (1), with p = 0.95, the minimum number of feet to be measured (n) with m = 1 mm is 332 and m = 2mm is 83.

To be able to measure the feet of diabetic patients with different levels of complications, we selected 2 specific medical locations as follows:

1) Khoai Chau Medical Center, Hung Yen province. At this Center, diabetic patients periodically come for examination and receive medication. Patients' feet usually have no complications or mild complications, and are at low and moderate risk of ulceration. The measurement period is from January 2023 to April 2023. Patients measured here are referred to as Group 1.

2) Department of Endocrinology, National Hospital of Endocrinology. This is a leading hospital specializing in diabetes treatment. At this hospital, not only patients in Hanoi but also

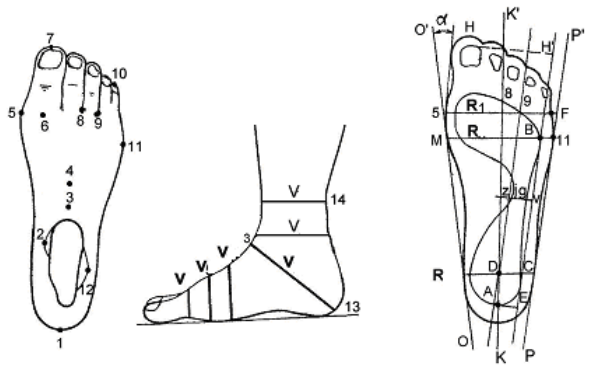
patients in the Northern provinces come for examination and treatment. Patients here suffered from various foot complications, with a higher risk of ulceration compared to group 1. The measurement period was from December 2023 to January 2024. Patients measured here are referred to as Group 2.

At these two locations, the feet of 332 men with diabetes were studied, specifically: Group 1 had 120 people, Group 2 had 212 people. The number of feet studied ensures representativeness and reliability of the research results.

2.2. Research Methods

2.2.1. Method of measuring feet

Direct measurement method is used to measure the patient's foot. The patient stands in an upright position, body weight evenly distributed on both feet, the distance between the feet is 20 cm [13, 19]. Measure both bare feet. Before measuring, we used a pen to mark anthropometric landmarks on the foot as shown in Fig. 1a, b [19].



a b c

Fig. 1. Foot anatomy landmarks and foot measurements.

1 - Pternion

2 - The most medial point of medial malleolus

3 - Junction point

4 - Top of instep point

5 - Metatarsale tibiale

6 - Top of ball girth point

7 - Tip of 1st toe

8 - Point between 2nd toe and 3th toe

9 - Point between 3th toe and 4th toe

10 - Tip of 5th toe

11 - Metatarsale fibulare

12 - The most lateral point of lateral malleolus

13 - Landing point

14 - Ankle point.

Foot parameters are determined as follows:

Lbc- Foot length: Distance from point 1 to point 7;

Lkt- Length to medial ball: Distance from point 1 to point 5;

Lkn- Length to lateral ball: Distance from point 1 to point 11;

Lngu- Length to the end of 5th toe: Distance from point 1 to point 10;

Rkt- Width of medial ball: Distance from point 5 to point F;

Rkn– Width of lateral ball: Distance from point 11 to point M;

Rkng– Width of ball: Distance from point 11 to point 5;

Rg– Width of heel: Measured at the widest part of the heel;

Vkt- Medial ball girth: Perimeter of cross-section measured through point 5;

Vkn- Lateral ball girth: Perimeter of cross-section measured through point 11;

Vkng- Ball girth: Perimeter of cross-section measured through point 5 and point 11;

Vgi- Waist girth: Perimeter of cross-section measured through point 4;

Vbu- Instep girth: Perimeter of cross-section measured through point 3;

*Vgo*t – Heel (cross) girth: Perimeter of cross-section measured through point 3 and 13;

Cnc- Height at 1st toe: Measured in the middle of 1st toe nail;

Ckt- Medial ball height- Height at point 6;

Cgi- Waist height - Height to point 4;

Cbu- Instep height - Height to point 3;

Cmc- Height at lateral ankle center- Height to point 12.

A small tape measure, a caliper, with an accuracy of ±1 mm, and a foot measuring device were used to measure the feet.

2.2.2. Method for assessing the condition of foot lesions

In addition to measurements, lesions/pathologies has been recorded according to the following symptoms:

- Normal foot without loss of protective sensation;
- Pain and swelling of the feet;
- Foot skin changes (dry, cracked skin);
- Calloused feet;

- Foot deformity, big toe curled outward/twisted;
- Foot ulcers;
- Loss/impairment of protective sensation;
- Amputation of the foot.

Procedure: We observed patients' feet, interviewed them, and photographed foot lesions with a digital camera.

2.2.3. Data processing

The maximum, minimum, mean and standard deviation values of the left and right foot parameters are determined and compared. The foot sizes of the patient groups were compared. The analysis of variance (ANOVA) was applied to confirm that there are no significant differences between the left and right foot of the study patients, as well as the difference between their feet parameters of patient groups. The calculated values are compared with $p = 0.05$ for a probability of 95% to determine if the results obtained are statistically significant. The values must be greater than $p = 0.05$ to confirm the null hypothesis.

The feet of male diabetic patients are evaluated according to each type of complications. From there, the proportion of feet that need to use different types of therapeutic shoes can be determined [9].

3. Results and Discussion

3.1. General Characteristics of Men with Diabetes

The average height of male patients studied was 164.5-165.1 cm, which is the average height of Vietnamese men (Table 1). Their average weight is 60.4 - 61.6 kg, the body mass index (BMI) is about 22.4, showing a normal body. Patients in group 1 had lower age (59.1 years) and diabetes duration (6.8 years) than patients in group 2 (63.9 years) and 9.9 years. According to age group (Table 2), group 1 has a large proportion of patients from 51 to 70 years old, about 83.7%. While the number of patients under 51 years old and from 71 to 80 years old accounts for a small proportion, 9.9% and 6.3% respectively. Group 1 has no patients over 80 years old. Meanwhile, group 2 has 48.3% of patients aged 61-70%. Patients from 51 to 60 and from 71 to 80 both account for 20%. Patients over 80 years old in group 2 account for 4.2%. This is reasonable because the National Hospital of Endocrinology often has to treat severe diabetes patients from many other provinces. Meanwhile, diabetes often tends to get worse over time or with the patient's age.

Group 1 has nearly half of the patients being farmers. Patients in group 2 who were officials and workers were higher at 24.2% and 26.5% respectively, while patients who were farmers decreased significantly to 33.5%.

Table 1. General information of men with diabetes

Information	Group 1			Group 2		
	Min	Max	Mean	Min	Max	Mean
Height, cm	153	180	164.5 ± 9.0	152	178	165.1± 5.5
Weight, kg	44	91	60.4 ± 8.0	38	92	61.6± 9.4
Age, years	44	79	59.1 ± 5.8	40	88	63.9±11.4
Duration of diabetes, years	1	16	6.8 ± 4.3	1	31	9.9±8.0

Table 2. Quantity of patients by age group

Age group, age	Group 1					
	≤50	51÷60	61÷70	71÷80	>80	Total
Quantity, people	22	96	90	14	0	222
Ratio, %	9.9	43.2	40.5	6.3	0	100
	Group 2					
Quantity, people	9	24	58	24	5	120
Ratio, %	7.5	20.0	48.3	20.0	4.2	100
Difference, %	*2.4*	*23.2*	*-7.8*	*-13.7*	*-4.2*	

Table 3. Occupational characteristics of patients

Occupation	Officer	Worker	Farmer	Other
	Group 1			
Quantity, people	29	35	104	43
Ratio, %	14.4	16.2	49.6	19.7
	Group 2			
Quantity, people	29	32	40	19
Ratio, %	24.2	26.5	33.5	15.8

3.2. Measurements of Male Diabetic Feet

The difference in values between the measurements of the right and left feet of each patient group is in Table 4.

The average values of the main measurements of length, width and height of the right and left feet of the 2 groups of patients (Table 4) differ by no more than 1.3 mm; the circumferences differ by no more than 2mm. The results of the ANOVA analysis showed that except the value of the big toe angle, there was no real difference in the main measurements of the left and right feet of the studied patients ($p>0.05$). The standard deviation of the left and right foot measurements of the 2 groups of patients differed by less than 1 mm. This is similar to the feet of people without diabetes [20]

Table 4. Difference in mean values of right and left foot measurements of 2 groups of patients

Foot measurements	Group 1								Group 2							
	Mean, mm					σ, mm			Mean, mm					σ, mm		
	Right foot	Left foot	Difference	Max. Difference	*p*	Right foot	Left foot	Difference	Right foot	Left foot	Difference	Max. Difference	*p*	Right foot	Left foot	Difference
Lbc	245	245.6	-0.6	8	*0.505*	8.7	9.3	-0.6	245.2	246.5	-1.3	10.0	*0.365*	11.0	11.5	-0.5
Lkt	176.9	177.6	-0.7	7	*0.358*	7.3	7.6	-0.3	176.8	176.1	0.8	11.0	*0.521*	9.3	9.7	-0.4
Lkn	154.8	156	-1.2	7	*0.219*	7.4	7	0.4	157.1	158.8	-1.7	10.0	*0.119*	8.0	8.4	-0.3
Lngu	202.3	204.3	-2.0	9	*0.564*	8.9	8.5	0.4	204.4	206.6	-2.2	13.0	*0.099*	10.1	10.4	-0.2
Lgot	40.1	41.1	-1.0	7	*0.496*	3.3	3.2	0.1	40.9	41.4	-0.5	9.0	*0.249*	3.1	3.6	-0.5
Rkt	99.2	98.3	0.9	7	*0.074*	6.8	5.5	1.3	96.2	97.1	-0.9	10.0	*0.234*	6.1	5.3	0.8
Rkn	94.3	96.1	-1.8	10	*0.092*	6	6	0.0	93.0	94.0	-1.1	10.0	*0.150*	5.8	5.8	0.0
Rkng	101.7	102.5	-0.8	9	*0.741*	6.1	5.9	0.2	100.2	100.1	0.1	11.0	*0.879*	6.3	5.5	0.8
Rg	64.6	64.5	0.1	6	*0.327*	3.6	4	-0.4	63.6	63.7	-0.1	9.0	*0.815*	4.3	4.5	-0.1
Cnc	20.7	20.1	0.6	2	*0.054*	2.1	2	0.1	20.7	21.1	-0.3	3.0	*0.178*	1.8	1.8	0.0
Ckt	33.9	33.3	0.6	3	*0.078*	3.3	2.9	0.4	34.3	34.8	-0.4	7.0	*0.276*	3.3	2.9	0.4
Cgi	55.3	56.1	-0.8	3	*0.116*	4.8	5.1	-0.3	59.5	59.2	0.3	9.0	*0.588*	4.7	5.1	-0.4
Cbu	68.4	68.4	0.0	5	*0.282*	5.5	5.9	-0.4	72.1	71.8	0.3	9.0	*0.704*	5.8	5.7	0.1
Cmc	61.5	60.8	0.7	4	*0.675*	4.7	5.2	-0.5	62.4	63.4	-1.0	11.0	*0.054*	3.4	3.9	-0.5
Vkt	229.2	228.2	1.0	9	*0.627*	12	11.9	0.1	225.5	226.4	-0.9	15.0	*0.578*	13.0	12.5	0.4
Vkn	233.4	233.1	0.3	11	*0.563*	11.7	11.6	0.1	231.7	231.0	0.7	15.0	*0.677*	13.2	12.8	0.4
Vkng	239.8	240.8	-1.0	9	*0.531*	12.4	12.3	0.1	239.1	239.3	-0.2	18.0	*0.884*	13.0	12.5	0.5
Vgi	235.6	235.8	-0.2	11	*0.631*	11.5	11.8	-0.3	237.0	236.0	0.9	15.0	*0.596*	13.8	13.7	0.1
Vbu	263	261.6	1.4	13	*0.411*	14.4	14	0.4	261.5	263.6	-2.1	23.0	*0.327*	16.2	16.9	-0.7
Vgot	313.5	315.5	-2.0	12	*0.682*	12.9	13.1	-0.2	311.6	311.8	-0.2	20.0	*0.914*	17.1	17.4	-0.4
Vco	202.5	203.6	-1.1	8	*0.690*	11.8	12.1	-0.3	200.6	200.0	0.6	10.0	*0.734*	14.1	13.6	0.4
Goc	5.9	6.9	-1.0	15	*0.009*	5.3	5.5	-0.2	5.8	9.0	-3.2	20.0	*0.000*	6.2	6.3	-0.1
H	0.6	0.8	-0.2	0.7	*0.053*	0.2	0.2	0.0	0.9	0.9	0.1	0.8	*0.055*	0.2	0.2	0.0

Table 5. Differences in mean values of foot parameters of patients in groups 1 and 2

Foot measurements	Mean. mm				σ. mm		
	Group 1	Group 2	Difference	*p*	Group 1	Group 2	Difference
Lbc	245.3	245.9	-0.6	*0.187*	9.0	11.2	-2.2
Lkt	177.3	176.4	0.8	*0.004*	7.5	9.5	-2.1
Lkn	155.4	158.0	-2.6	*0.041*	7.2	8.2	-1.0
Lngu	203.3	205.5	-2.2	*0.005*	8.7	10.3	-1.6
Lgot	40.6	41.1	-0.5	*0.000*	3.3	3.3	-0.1
Rkt	98.8	96.6	2.1	*0.000*	6.2	5.7	0.4
Rkn	95.2	93.5	1.7	*0.000*	6.0	5.8	0.2
Rkng	101.5	100.1	1.4	*0.003*	6.0	6.9	-0.9
Rg	64.6	63.7	0.9	*0.001*	3.8	4.4	-0.6
Cnc	20.4	20.9	-0.5	*0.001*	2.1	1.8	0.3
Ckt	33.6	34.5	-0.9	*0.000*	3.1	3.1	0.0
Cgi	55.7	58.4	-2.7	*0.000*	5.0	4.9	0.1
Cbu	68.4	70.9	-2.5	*0.000*	5.7	5.8	-0.1
Cmc	61.2	62.9	-1.7	*0.000*	5.0	3.7	1.3
Vkt	228.7	225.9	2.8	*0.000*	12.0	12.7	-0.8
Vkn	233.3	231.4	1.9	*0.003*	11.7	13.0	-1.3
Vkng	240.3	239.2	1.1	*0.017*	11.4	12.8	-1.4
Vgi	235.7	236.5	-0.8	*0.002*	11.7	13.7	-2.1
Vbu	262.3	262.5	-0.2	*0.001*	14.2	16.6	-2.4
Vgot	314.5	311.7	2.8	*0.009*	13.0	17.2	-4.2
Vco	202.5	200.3	2.2	*0.001*	12.0	13.9	-1.9
Goc	6.4	7.4	-1.0	*0.015*	5.4	6.3	-0.9
H	0.7	0.9	-0.1	*0.023*	0.2	0.2	0.0

The mean values of the main measurements of the feet of patients in groups 1 and 2 were different. *Lbc* leg length difference is 0.6 mm. The circumference of balls *Vkng* differs by 1.1 mm. The width of the balls varied by 1.4 mm (Table 5). The biggest difference is in foot height. The foot height of patients in group 2 was greater than that of patients in group 1, while the foot circumference parameter is less than 2.6 mm.

The value of the big toe angle of the feet of group 2 patients is smaller than that of group 1 patients. This is because the patient's big toe tends to push outward over time with the disease. The same thing happens with the foot arch coefficient. This value in the feet of patients in group 2 is 0.9, greater than that of patients in group 1, which is 0.7. This suggests that diabetic feet tend to have lower arches over time. Therefore, using molded insoles/customized insoles is very helpful for diabetics.

According to the ANOVA analysis results in Table 5, there was no real difference in the foot length size Lbc of both patient groups (p>0.05). Meanwhile, there are real differences in the values of all remaining parameters of the feet of patients in groups 1 and 2 (p<0.05). This is also seen through the standard deviation of the foot measurements of the 2 groups of patients. The standard deviation of most foot measurements of patients in group 2 is larger than that of group 1. The large standard deviation value also represents a large fluctuation in the values of foot parameters in group 2 patients. Thus, according to the results in Table 5, it is not recommended to combine the foot measurement values of the two groups of patients to build a foot size system for the purpose of designing shoe lasts, designing and manufacturing "Extra Depth Diabetic Shoes" for patients. For this purpose, the foot size system that has been developed in published research should be used [17].

To evaluate the influence of age on the values of foot parameters, we compared the average values of foot measurements according to 3 age groups (51÷60, 61÷70 and 71÷80). These are groups that account for a large proportion of the total number of patients in group 2. The results in Table 6 show that there is no large difference in the average value of foot measurements by each age group compared to the average of group 2. Foot length *Lbc* difference is 1.3 mm, ball width *Rkng* is not more than 1mm and ball circumference *Vkng* is not more than 1.4 mm. ANOVA analysis results showed that there was no real difference in the values of these 3 main measurements of patients' feet according to age groups compared to the average value of group 2 (p>0.05). Similar results were also achieved for the age groups of patients in group 1.

Table 6. Average values of foot parameters of patients in group 2 according to 3 age groups

Foot measurements	Mean, mm	Average value of foot measurements by age groups					
		51÷60		61÷70		71÷80	
		Mean, mm	Difference	Mean, mm	Difference	Mean, mm	Difference
Lbc	*245.9*	*244.6*	*-1.3*	*246.6*	*0.7*	*245.2*	*-0.6*
Lkt	176.4	174.0	-2.4	176.8	0.3	176.8	0.4
Lkn	158.0	156.2	-1.8	158.6	0.6	158.1	0.2
Lngu	205.5	203.6	-2.0	206.9	1.3	205.2	-0.3
Lgot	41.1	39.9	-1.2	41.8	0.7	40.9	-0.2
Rkt	96.6	95.5	-1.1	96.9	0.2	96.9	0.3
Rkn	93.5	92.6	-0.9	93.7	0.2	93.6	0.1
Rkng	*100.1*	*99.1*	*-1.0*	*100.1*	*0.0*	*100.5*	*0.3*
Rg	63.7	61.5	-2.2	63.9	0.3	64.7	1.1
Cnc	20.9	20.6	-0.3	21.1	0.2	21.0	0.1
Ckt	34.5	34.6	0.1	34.7	0.2	35.1	0.6
Cgi	59.4	58.4	-1.0	60.8	1.4	58.8	-0.6
Cbu	71.9	71.6	-0.3	73.2	1.3	71.2	-0.8
Cmc	62.9	62.3	-0.6	63.6	0.8	62.4	-0.5
Vkt	225.9	224.9	-1.0	226.7	0.8	225.8	-0.1
Vkn	231.4	230.7	-0.6	231.6	0.3	231.3	-0.1
Vkng	*239.2*	*238.5*	*-0.6*	*240.0*	*0.8*	*237.8*	*-1.4*
Vgi	236.5	235.1	-1.4	237.5	1.0	236.3	-0.2
Vbu	262.5	259.8	-2.8	263.4	0.9	263.8	1.3
Vgot	311.7	308.2	-3.5	312.5	0.9	314.1	2.4
Vco	200.3	198.4	-1.9	201.9	1.7	201.1	0.9
Goc	7.4	8.2	0.7	6.6	-0.8	8.8	1.4
H	0.8	0.8	0.0	0.7	0.0	0.7	-0.1

Table 7. Comparison of foot measurements by two age groups of two patient groups

Foot measurements	Age group					
	51-60		Difference	61-70		Difference
	Group 1	Group 2		Group 1	Group 2	
Lbc	245.6	*244.6*	1.0	246.7	*246.6*	0.1
Lkt	172.8	174.0	-1.2	174.0	176.8	-2.8
Lkn	154.5	156.2	-1.7	157.8	158.6	-0.8
Lngu	202.7	203.6	-0.9	205.4	206.9	-1.5
Lgot	38.8	39.9	-1.1	41.8	41.8	0.0
Rkt	94.3	95.5	-1.2	95.8	96.9	-1.1
Rkn	90.5	92.6	-1.9	92.5	93.7	-1.2
Rkng	97.4	*99.1*	-1.7	98.6	*100.1*	-1.5
Rg	59.0	61.5	-2.5	63.2	63.9	-0.7
Cnc	20.1	20.6	-0.5	20.6	21.1	-0.5
Ckt	33.9	34.6	-0.7	34.1	34.7	-0.6
Cgi	55.1	58.4	-3.3	58.0	60.8	-2.8
Cbu	68.3	71.6	-3.3	70.7	73.2	-2.5
Cmc	61.2	62.3	-1.1	62.5	63.6	-1.1
Vkt	222.3	224.9	-2.6	224.3	226.7	-2.4
Vkn	228.9	230.7	-1.8	231.1	231.6	-0.5
Vkng	236.0	*238.5*	-2.5	238.8	*240.0*	-1.2
Vbu	257.7	259.8	-2.1	263.0	263.4	-0.4
Vgot	304.2	308.2	-4.0	308.8	312.5	-3.7
Vco	198.1	198.4	-0.3	204.8	201.9	2.9
H	0.7	0.8	-0.1	0.6	0.7	-0.1

Thus, it can be observed that for both groups of patients, there is no significant difference in foot measurement values between age groups. Data in Table 7 show that there is a difference in foot measurements of the two patient groups according to age group (p<0.05). Group 2 patients' feet tend to be wider and larger in circumference. The arch of the foot is lower than the foot of group 1 patients. This is because the patient's foot tends to become deformed, joint swollen and edematous over time of illness. Thus, the difference in foot measurements between the 2 groups of patients is not much affected by age but depends mainly on the level of foot complications. This shows that evaluating the foot according to the level of complications is necessary to determine the type of shoe the patient should use.

3.3. Foot Lesions of Men with Diabetes

Shoes/shoe insoles for diabetic patients, in addition to meeting foot-fitting requirements, must also meet the requirements of reducing pressure on the foot plantar, reducing peak pressure that can cause foot ulcers. Therefore, to design and manufacture shoes/shoe insoles for diabetic patients, in addition to foot parameters, it is necessary to pay attention to the characteristics of foot shape and its types of lesions that can lead to the risk of foot ulcers. The proportion of patients' feet with different complications is listed in Table 8.

Table 8. Complications of male diabetic foot

Complications	Group 1		Group 2		Type of shoes
	Ratio, %	Duration of diabetes, years	Ratio, %	Duration of diabetes, years	
The foot has no complications/feels normal	45.6	3.64 ± 2.1	27.3	4.28 ± 2.5	A5500
Leg pain and swelling	19.8	3.90 ± 1.9	35.5	6.90 ± 2.7	A5500; A5512*
Skin changes (dry, cracked skin)	12.0	4.0 ± 2.9	25.9	5.7± 2.9	A5500; A5512*
Corn	15.8	4.20 ± 3.0	28.4	6.80 ± 4.2	A5500; A5512*
Deformity of the foot, big toe curled/turned out	12.5	5.10 ± 3.8	21.5	8.20 ± 5.7	A5512; A5513*
Foot ulcers	5.4	6.21± 4.4	8.1	8.28 ± 5.2	A5512; A5513**
Impairment/loss of protective sensation	4.4	6.91± 6.0	7.5	7.25 ± 6.2	A5512; A5513**
Amputation of the foot	0	0	0.1	15	A5513
Total	110.1		145.7		

*Notes: * cases of ulcers on the foot plantar and reduced/lost protective sensation.*
***cases where the foot is deformed and loses protective sensation.*

The diabetes status of group 1 is basically mild, so the number of patients with uncomplicated feet accounts for 43.6%. Patients in group 2 had more severe disease. Therefore, the proportion of patients with normal feet decreased to 23.5%, while the proportion of feet with all types of damage increased sharply. The rate of feet with ulcers or a history of ulcers is quite high at 9.1%. One patient had part of the tip of one foot amputated. The number of patients suffering from 2 types of foot injuries accounts for more than 45.7%.

Based on the instructions for using therapeutic shoes/insoles according to the US Medicare Program [9], the ratio of shoe types needed for patients has been calculated in Table 9.

Table 9. Statistics of shoe types for men with diabetes

Shoe types	Group 1	Group 2	For both groups
A5500, %	84.5	66.5	75.4
A5512, %	14	28.6	21.8
A5513, %	1.5	4.9	3.2
Total, %	100	100	100

Thus, up to 97.2% of male patients need to use "Extra Depth Diabetic Shoes", of which 75.4% of patients use "Diabetic Inlays", and 21.8% of patients use “Custom Molded Inlays”; 3.2% of patients used “Custom Molded Diabetic Shoes” and “Custom Molded Inlays”.

4. Conclusion

Foot complications in men with diabetes tend to get worse over time. Foot damage/pathology is the main cause of discrepancies in height, width and foot circumference measurements. This difference does not depend on age. Therefore, the type of "Extra Depth Diabetic Shoes" cannot satisfy the requirements of diabetic patients whose feet have different levels of complications. In addition to this type of shoe, it is necessary to design and manufacture "Custom Molded Diabetic Shoes" and "Custom Molded Inlays" for patients with severe foot complications. 3D printing technology will greatly support the production of this type of shoe at a reasonable cost. To design and manufacture shoes for diabetic patients, it is necessary to study the shape and size of the foot, and evaluate the degree of foot damage.

According to the evolution of the feet of men with diabetes, up to 97.2% of male patients need to use " Extra Depth Diabetic Shoes", 21.8% of patients need "Custom Molded Inlay"; 3.2% of patients need “Custom Molded Diabetic Shoes”. The results of this study are the basis for designing and manufacturing shoes for Vietnamese men with diabetes according to the patient's anthropometric characteristics and foot complications.

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