RESEARCH ON FOOT ANTHROPOMETRY OF MEN WITH DIABETES IN VIETNAM

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ABSTRACT. Diabetes often causes foot complications, inducing diabetic patients to use therapy shoes or custom-made shoes designed on the basis of anthropometric characteristics of their feet to ensure a good fitting. Wearing poorly fitted shoes contributes to the development of foot ulcer sites. This paper presents the results of foot anthropometric research, developing a foot size system for men with diabetes in Vietnam in order to develop pressure-offloading footwear. The foot data of 212 men with type-2 diabetes aged 44 to 75 years were collected during this study. Foot photography and patient interviews about foot complications were also conducted by research assistants. The results show that the average disease duration of the surveyed patients was statistically calculated as 6.8 ± 4.3 years. The patients from 50 to 70 years old accounted for up to 86.8% of all interviewees. In all participants, the patients with foot pain and swelling of metatarsal joints accounted for 19.8%, foot ulcers accounted for 6.4%, dry feet, cracked skin, and calluses almost equally accounted for 12%. Most of the feet are slightly deformed mainly in the metatarsal joint area and no patient had a leg amputation. The patients suffering from two types of foot injuries account for more than 43.1%. Interestingly, the ball width and circumference of the patient's foot are 4.5 mm and 6.5 mm larger than that of a healthy man's foot, respectively; whereas, the mid-foot height is 3.7 mm lower. From the collected data and statistic figures, the patient foot sizing system has been developed including 5 sizes by length (231.5, 238.0, 244.5, 251.0, 257.5 mm), and each size by length is divided into 3 sizes by width. Our categorizing system meets more than 81.5% of the shoe size needed by men with diabetes in Vietnam.

KEY WORDS: diabetic foot, foot anthropometry, foot ulcers

CERCETĂRI PRIVIND ANTROPOMETRIA PICIORULUI LA BĂRBAȚII CU DIABET DIN VIETNAM

REZUMAT. Diabetul provoacă adesea complicații ale picioarelor, determinând pacienții diabetici să folosească încălțăminte terapeutică sau încălțăminte personalizată concepută pe baza caracteristicilor antropometrice ale picioarelor pentru a le asigura o potrivire bună. Purtarea pantofilor nepotriviți contribuie la dezvoltarea zonelor ulceroase ale piciorului. Această lucrare prezintă rezultatele cercetării antropometrice ale piciorului, dezvoltând un sistem de mărime a piciorului pentru bărbații cu diabet din Vietnam, în scopul dezvoltării unui tip de încălțăminte care să atenueze presiunea. În acest studiu s-au colectat datele a 212 bărbați cu diabet zaharat de tip 2 cu vârsta cuprinsă între 44 și 75 de ani. Fotografiile picioarelor și interviurile cu pacienții despre complicațiile la nivelul picioarelor au fost, de asemenea, efectuate de asistenți de cercetare. Rezultatele arată că durata medie a bolii la pacienții chestionați a fost calculată statistic ca fiind de 6,8 ± 4,3 ani. Pacienții cu vârsta cuprinsă între 50 și 70 de ani au reprezentat până la 86,8% din toți cei intervievați. Din toți participanții, pacienții cu dureri de picior și articulații metatarsiene umflate au reprezentat 19,8%, ulcerele piciorului au reprezentat 6,4%, picioarele uscate, pielea crăpată și calusurile au reprezentat aproape în egală măsură 12%. Majoritatea picioarelor sunt ușor deformate în principal în zona articulației metatarsiene și niciun pacient nu a avut amputație de picior. Pacienții care suferă de două tipuri de leziuni ale picioarelor reprezintă mai mult de 43,1%. Interesant este că lățimea și circumferința zonei metatarso-falangiene a pacientului sunt cu 4,5 mm și, respectiv, 6,5 mm mai mari decât cea a piciorului unui bărbat sănătos; în timp ce înălțimea în zona mediană a piciorului este cu 3,7 mm mai mică. Pornind de la datele colectate și cifrele statistice, s-a dezvoltat sistemul de dimensionare a piciorului pacientului incluzând 5 dimensiuni după lungime (231,5, 238,0, 244,5, 251,0, 257,5 mm), iar fiecare dimensiune după lungime este împărțită în 3 mărimi după lățime. Sistemul nostru de clasificare acoperă mai mult de 81,5% din mărimea pantofilor necesară bărbaților cu diabet din Vietnam.

CUVINTE CHEIE: picior diabetic, antropometria piciorului, ulcerul piciorului

RECHERCHE SUR L'ANTHROPOMÉTRIE DU PIED DES HOMMES DIABÉTIQUES AU VIETNAM

RÉSUMÉ. Le diabète entraîne souvent des complications du pied, incitant les patients diabétiques à utiliser des chaussures thérapeutiques ou des chaussures sur mesure conçues sur la base des caractéristiques anthropométriques de leurs pieds pour assurer un bon ajustement. Le port de chaussures mal ajustées contribue au développement de sites d'ulcères du pied. Cet article présente les résultats de la recherche anthropométrique du pied, développant un système de taille de pied pour les hommes diabétiques au Vietnam afin de développer des chaussures de décharge de pression. Les données des pieds de 212 hommes atteints de diabète de type 2 âgés de 44 à 75 ans ont été recueillies au cours de cette étude. Des photographies de pieds et des entretiens avec des patients sur les complications du pied ont également été réalisés par des assistants de recherche. Les résultats montrent que la durée moyenne de la maladie des patients interrogés a été calculée statistiquement à 6,8 ± 4,3 ans. Les patients de 50 à 70 ans représentaient jusqu'à 86,8 % de toutes les personnes interrogées. Chez tous les participants, les patients souffrant de douleurs aux pieds et de gonflement des articulations métatarsiennes représentaient 19,8 %, les ulcères du pied représentaient 6,4 %, les pieds secs, la peau craquelée et les callosités représentaient presque également 12 %. La plupart des pieds sont légèrement déformés principalement au niveau de l'articulation métatarsienne et aucun patient n'a subi d'amputation de pied. Les patients souffrant de deux types de blessures aux pieds représentent plus de 43,1 %. Fait intéressant, la largeur et la circonférence de la balle du pied du patient sont supérieures, de 4,5 mm et 6,5 mm, respectivement, à celles du pied d'un homme en bonne santé ; tandis que la hauteur du milieu du pied est inférieure, de 3,7 mm. À partir des données collectées et des chiffres statistiques, le système de dimensionnement du pied du patient a été développé, comprenant 5 tailles par longueur (231,5, 238,0, 244,5, 251,0, 257,5 mm), et chaque taille par longueur est divisée en 3 tailles par largeur. Notre système de catégorisation répond à plus de 81,5 % de la pointure nécessaire aux hommes atteints de diabète au Vietnam.

MOTS CLÉS : pied diabétique, anthropométrie du pied, ulcères du pied

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INTRODUCTION

Diabetes is a disease occurring when blood glucose – hyperglycemia – raises to high levels or stays unstable. Foot injury is a common complication ensuing diabetes, including foot pain, skin changes, calluses, foot deformities, ulcers, and amputation [1-3]. Muscle atrophy in the diabetic foot causes convex and concave muscle surface, increasing the pressure when walking, this is the major effect leading to foot ulcers [4]. The microvascular and peripheral nerves of the damaged foot inflict loss of sensation. Foot complications lead to changes in the shape and parameters of the patient's feet. In addition, the repetitive pressure of body weight on the feet, while walking, raises amputation risk.

There are many factors that affect diabetic foot complications such as duration of illness, the severity of disease, age, gender, living and working environmental conditions, foot care, use of footwear, and so on [2, 3]. Among the various types of foot lesions, foot ulcers are the most common problem in diabetic feet that fifteen percent of diabetic patients worldwide may develop. Previously published studies have found that the majority of ulcers originate from the plantar areas of the feet. Most foot ulcers are found in the plantar area due to peak plantar pressure, abnormal foot shape, toe deformity, and insensate foot. They usually develop under the tips of the metatarsal joints and in the toes [1, 5-8]. Studies on the foot injury of diabetic patients in Vietnam specifically found that the rate of foot ulceration ranged from 28.9% to 43.62%. And the ulcers also grow mainly on the forepart of the foot plantar. One of the main causes of foot ulcers is that patients do not use comfortable and appropriate footwear, in many cases they do not use footwear in the least [9-12].

Adequate footwear, distributing pressures across the foot to lessen stress at targeted regions, can play an important role in preventing the risk of foot ulceration. Therapy shoes and custom-made shoes are designed according to the patient's foot anthropometric characteristics to relieve mechanical pressure. The differences in the parameters of the right foot and the left foot have been studied to be insignificant [13-16]. Several studies have compared diabetic foot parameters with those of healthy human feet. Their results found that first of all, the foot length of diabetic patients did not differ from that of healthy subjects [14-16], or no more than 3 mm deviation [13]. Their width parameters may be wider [13, 15-17] or equal in other cases [14]. Finally, foot circumference is mostly larger than that of a healthy person's foot [12-16]. Interestingly, main divergences depend significantly on age group, sex, and body mass indexes [18]. Therefore, it is necessary to study the foot anthropometry of patients with diabetes regarding the abovementioned factors before manufacturing footwear to prevent foot ulceration [18].

Anthropometric characteristics of human feet are affected by many factors such as race, gender, age, living conditions, and geographical inhabitation [19]. Meanwhile, there have been not so many studies conducted respecting foot anthropometry in diabetic patients for the purpose of designing and fabricating footwear in Vietnam. Currently, in Vietnam there are no therapeutic shoes or customized shoes to reduce the incidence of neuropathic ulcers in high-risk diabetic patients. Patients, therefore, employ casual footwear which does not fit the characteristics of the diabetic feet, exposing them to indirect damage as well as irritation. And this is also one of the reasons increasing the rate of foot ulcers in patients caused by plantar and dorsal surface stress [9-12]. Recently, scientists have begun to study the sex factor in designing shoes for male and female diabetic patients, because varied sensory perceptions influence customized products [15, 16]. However, there have been no studies on foot anthropometry of Vietnamese males and females with diabetes, the basis for designing and manufacturing therapeutic shoes for patients.

This study focuses on evaluating anthropometric characteristics of the feet of diabetic males in Vietnam to construct a parameter system of the foot size. We used measuring instruments to collect foot data from 212 diabetic men with foot lesions photographed.

The patients were interviewed directly to clarify the history of foot complications. The foot anthropometric characteristics of the patients were evaluated by comparing their foot parameters with the same foot parameters of healthy men. Based on the collected data, a foot size system was built for the purpose of designing shoe shapes, providing therapeutic footwear for patients.

EXPERIMENTAL

Materials and Methods

Subjects

The subjects of this study are the feet of men with type 2 diabetes. They are usually examined and receive medication at the local health centers in Vietnam. This is a group of patients with low and moderate risk of foot ulcers. They should be able to use "Extra Depth Diabetic Shoes" or therapeutic shoes [20]. Some information about the studied diabetic patients is shown in Table 1.

Table 1: Some information about the studied diabetic patients

	Min	Max	Averaged ± SD
Age, year	44	75	59.1 ± 5.8
Body height, cm	153	180	164.5 ± 9.0
Weight, kg	44	91	60.4 ± 8.0
Disease duration, years	1	16	6.8 ± 4.3

Among the surveyed patients, by occupation, civil servants are 14.8%, workers are 15.8%, farmers are 49.6%, others are 19.7%.

Measurement Method

In this study, the direct measurement method [19] was used to measure the feet of diabetic patients. Feet are measured in the upright standing position, body weight evenly distributed on both feet. The distance between the two feet is 20 cm. Both patient feet were measured. The foot measuring device includes a soft narrow tape measure, a caliper with a 1 mm scale, a footprint device, and a camera. Measurement time is from 9 am to 11 am on weekdays. The anthropometric points on the foot and the way to measure the foot sizes are shown in figure 1 [19].

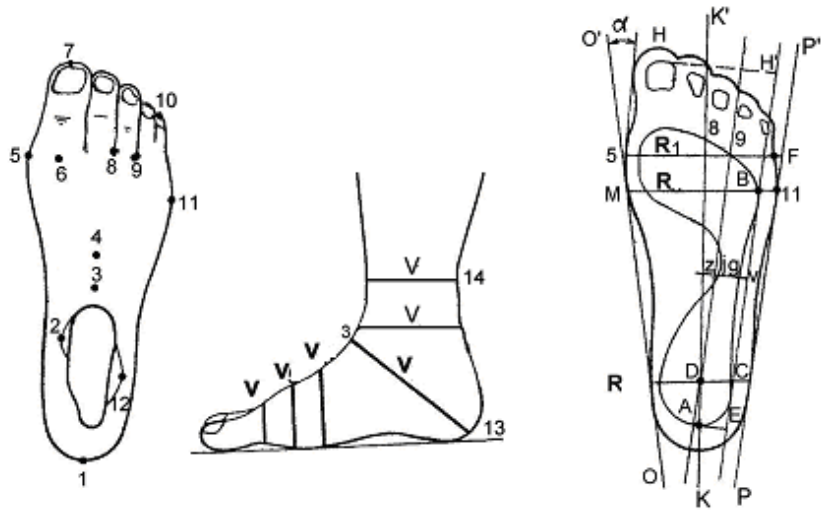


Figure 1. Foot anatomy points and foot measurements

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 3rd toe
9 – Point between 3rd 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 length and width parameters are determined by its contour (Figure 1 c):

Lf – Foot length: Distance from point 1 to point 7;

Lmb – Length to medial ball: Distance from point 1 to point 5;

Llb – Length to lateral ball: Distance from point 1 to point 11;

L5toe – Length to the end of 5th toe: Distance from point 1 to point 10;

Lla – Length to center of lateral ankle: Distance from point 1 to point 12;

Rmb – Width of medial ball: Distance from point 5 to point F;

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

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

Rh – Width of heel: Measured at the widest part of the heel.

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

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

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

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

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

Vh – Heel (cross) girth: Perimeter of cross-section measured through points 3 and 13;

Va – Ankle girth: Perimeter of cross-section measured through point 14;

C1toe – Height at 1st toe: Measured in the middle of 1st toenail;

Cmb – Medial ball height- Height at point 6;

Cins – Instep height - Height to point 3;

Cla – Height at lateral ankle center: Height to point 12;

H – Longitudinal arch factor: Determined by footprint parameters (ratio of ig/zv) (see Fig. 1c) [19]:

H-value from 0 to 0.51: high arch feet;
H-value from 0.51 to 1.1: Normal foot;
H-value from 1.11 to 1.3: Low arched foot;
H-value from 1.31 to 1.5: Flat foot.

α – Angle of the big toe: determined by foot contour (see Fig. 1c).

In addition to measurements, lesions of the foot such as joint swelling, ulceration, edema have been recorded. The feet were also

photographed. The research team talked to and interviewed the patients to get information about the history and progression of foot complications.

Data Processing

According to foot images and patient interview results, the extent and types of foot complications were evaluated. The maximum, minimum, and mean and standard deviation values of the left and right feet parameters are determined and compared. The values of the surveyed foot parameters were compared with those of healthy men's feet [21]. Regression equations and correlation coefficients between foot parameters, and foot parameters system were built [19].

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 and that of the healthy men's feet. 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.

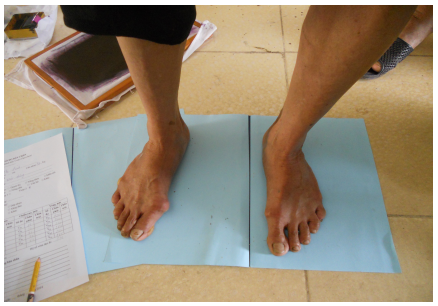
RESULTS AND DISCUSSIONS

Complication Characteristics of Diabetic Men's Feet

Observations recorded during the foot measurement of diabetic men showed that calluses were concentrated in the ball joints, toes, and ankles. The proportion of patients with swollen, slightly deformed medial ball joints accounted for 32.5%. Statistics of types of foot lesions in diabetic men are shown in Table 2.

Table 2: Types of foot lesions in diabetic men

Types of foot injuries	Ratio, %	Disease duration, years	Image of foot injury
Uncomplicated feet	33.6	3.64 ± 2.1	
Foot pain and ball swelling	19.8	3.90± 1.9	
Skin changes (dry, cracked skin)	12.0	4.1 ± 2.9	

Types of foot injuries	Ratio, %	Disease duration, years	Image of foot injury
Calloused feet	15.8	4,20 ± 3,0	
Deformed foot	12.5	5.10 ± 3.8	
Foot ulcers	6.4	6.21± 4.4	
Total	143.1		

The number of patients with unaffected feet accounted for nearly 33.6%, and 18.8% lower than female diabetic patients [12]. The feet of these patients were similar to those of healthy men. Feet with painful and swollen ball joints accounted for 19.8%, foot ulcers accounted for 6.4%, dry feet, cracked skin and foot callus are almost equal, accounting for about 12%. The degree of foot deformity of the patient is mild. The deformed position is mainly in the ball joint area. No patient had foot amputation, lost foot sensation. The extent of foot damage increases with the duration of the disease. The number of patients suffering from 2 types of foot injuries is relatively high, accounting for more than 43.1%, and 17.4% higher than female diabetic patients [12].

Main Foot Anthropometric Characteristics of the Studied Diabetic Man

The results of measurement data processing showed that there was no difference ($p > 0.05$) between the parameters of length, width, height, and circumference of the right and left feet of men with diabetes. This result is similar to that of female diabetic feet in Vietnam [16], as well as the results of published research [13-16].

Anthropometric features of the foot of diabetic men compared with normal foot size have been published [21] as shown in Table 3.

Table 3: The size of diabetic men's feet and normal men's feet

Foot size	Men's foot parameters, mm			*p* -value
	Diabetic patient	Healthy	Different	
Lf	244.3±8.8	245.0±10.7	-0.7	0.45
Lmb	179.6±7.8	175.7±9.4	3.9	0.123
Llb	159.2±7.4	156.2±9.2	3	0.015
L5toe	202.0±8.2	195.4±10.6	6.6	0.025
Rmb	99.7±7.2	95.6±4.9	4.1	0.002
Rlb	96.1±7.2	94.1±5.0	2	0.057
Rb	102.9±7.2	98.4±5.1	4.5	0.004
Rh	65.4±5.7	61.0±4.0	4.4	0.005
C1toe	19.8±2.4	19.1±2.2	0.7	0.105
Cmb	32.9±3.3	35.6±3.2	-2.7	0.052
Cins	53.4±5.1	57.1±5.3	-3.7	0.007
Cla	59.6±5.2	69.2±5.7	-9.6	0.008
Vmb	230.8±13.0	225.3±11.2	5.5	0.016
Vlb	235.0±12.4	230.6±11.5	4.4	0.028
Vb	241.0±13.5	234.8±11.9	6.2	0.019
Vw	235.2±12.5	231.6±11.6	3.6	0.048
Vins	245.1±12.9	240.3±12.1	4.8	0.031
Vh	318.8±17.0	315.6±15.8	3.2	0.086
Va	237.6±13.8	233.5±12.7	4.1	0.069
H	1.21±0.34	1.02±0.28	0.19	0.029
α	4.80 ± 6.3	2.50 ± 4.2	3.3	0.066

According to the data in Table 3, there was no difference in foot length of diabetic men and healthy men's feet. The foot width and girth of diabetic men are larger than that of healthy men. Specifically, the width of the ball joint is greater than 4.5 mm, the ball girth is greater than 6.2 mm. The standard deviation of the foot width sizes and girth of diabetic men is larger than that of healthy men. The cause may be due to complications of swollen ball joints in the feet of diabetic patients. In contrast, the foot height of diabetic men is smaller than that of healthy men. For example, the midfoot height is less than 3.7 mm. This is reasonable since compared with the healthy man's feet, the medial longitudinal arch of the diabetic man's feet is lower ($p<0.05$). In addition, this problem may be related to tissue atrophy in the plantar of the diabetic feet. This can also be the cause of the increase in their width parameters. There was no significant difference ($p>0.05$) between the hallux angle of the patient's foot and that of the healthy man's foot.

Building the Foot Size System for Diabetic Men

Foot length is often the dominant parameter for building a length size system. The ball girth is usually the dominant parameter for sizing by width. For the studied diabetic men's feet, the measured and theoretical (normal distribution) curves of the length and ball girth were quite close to each other (Figures 2 and 3). The calculated values of c^2 according to the foot length and ball girth, respectively 5.2 and 9.0, are smaller than the value of c^2 in the table with a probability of 95%. This confirms that these parameters are suitable as the dominant for the building of the foot size system [19].

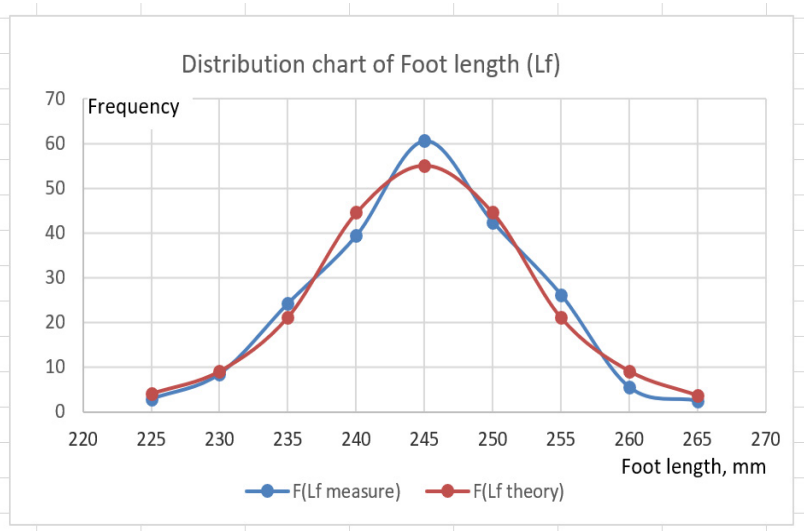


Figure 2. Theoretical and practical distribution charts by foot length

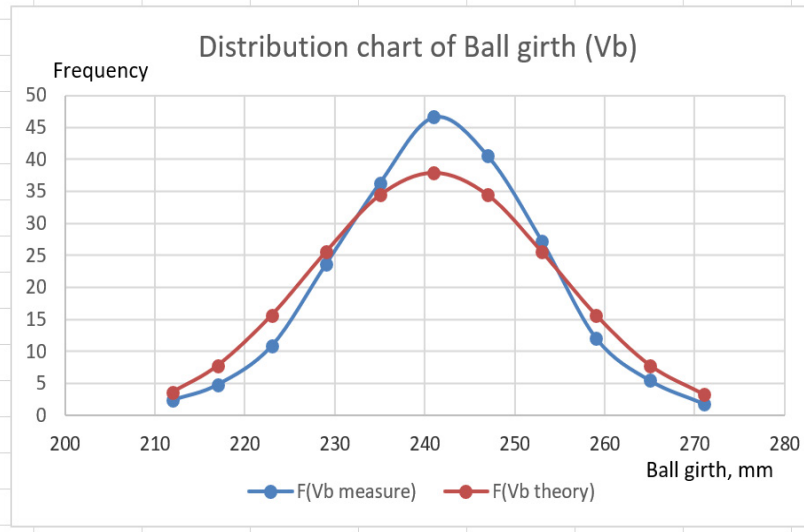


Figure 3. Theoretical and practical distribution charts by ball girth

According to the measured data, regression equations and correlation coefficient r have been built. They show the relationship between the patient's foot remaining parameters and the dominant parameters (Table 4).

Table 4: Regression equations of diabetic men's feet

N^o	Foot parameters	Regression	r	*p*
1	Lmb	Lkt = 0.736 Lf	0.85	< 0.005
2	Llb	Lkn = 0.652Lf	0.83	< 0.005
3	L5toe	L5toe = 0.828Lf	0.87	< 0.005
4	Lla	Lla = 0.228Lf	0.48	< 0.050
5	Rmb	Rmb = 0.413Vb	0.65	< 0.005
6	Rlb	Rlb = 0.399Vb	0.73	< 0.005
7	Rb	Rb = 0.427Vb	0.75	< 0.005
8	Rh	Rh = 0.271Vb	0.35	< 0.050
9	C1toe	C1toe = 0.083Vb	0.50	< 0.050
10	Cmb	Cmb = 0.136Vb	0.45	< 0.050
11	Cins	Cins = 0.221Vb	0.51	< 0.050
12	Cla	Cla = 0.247Vb	0.78	< 0.005
13	Vmb	Vmb = 0.957Vb	0.88	< 0.005
14	Vlb	Vlb = 0.975Vb	0.89	< 0.005

N°	Foot parameters	Regression	r	p
15	Vw	Vw = 0.976Vb	0.86	< 0.005
16	Vins	Vins = 1.017Vb	0.84	< 0.005
17	Vh	Vh = 1.306Vb	0.72	< 0.005
18	Va	Va = 0.850Vb	0.64	< 0.005

Currently, the most commonly used shoe size systems are the French (European), British, American, and Mondopoint sizing systems. The basis for determining shoe sizes of the French, British and American size systems is the insole length. The length increments for these size systems are 6.66 mm (French system), 8.46 mm (British and American systems), and are 3.33 and 4.23 mm, respectively. The Mondopoint sizing system determines the size according to the foot length. The increments in foot length are 10 mm, for half size is 5 mm.

Research results on female diabetic feet in Vietnam [15, 16] show that the French size system, with length increments of 6.66 mm, can be rounded by 6.5 mm, which is a reasonable choice. This increment is about two-thirds of the standard deviation of the foot length, making it easy to choose shoes, as well as ensuring the right number of sizes. Therefore, in this study, the foot size system was also built on the basis of the French size system.

Building the Size Structure by Foot Length

The theoretical value of the part a_j of size j is equal to the probability (frequency) of the normal distribution of the value Bз in the corresponding j interval $(X_j^н, X_j^в)$, where $X_j^н$, $X_j^в$ are the lower and upper limits of the j interval [27]. $a_j = P(X_j^н < Bз < X_j^в) » Φ(Z_j^в) – Φ(Z_j^н)$, where Φ(Z) – Laplace function, defined according to the table of values by the values of $Z_j^в$ and $Z_j^н$: $Z_j^в = (X_j^в – X)/d$ and $Z_j^н = (X_j^н – X)/d$ (where d is the standard deviation). The set of a_j values for all foot length classes is the foot size structure by length [19] (see Table 5).

Table 5: Results of calculating the foot size structure by length

Foot sizes by length, mm	Limit values of the class X, mm		Standard value Z		Values of the Laplace function Φ(Z)		$P(Bз_j^н <Bз<Bз_j^в)$	Relative percentage $α_j$
	$Bз_j^н$	$Bз_j^в$	$Z_j^н$	$Z_j^в$	$Φ(Z_j^н)$	$Φ(Z_j^в)$		
218.5	216	221	-3.2386	-2.670	0.0010	0.0038	0.003	0.003
225.0	222	228	-2.5568	-1.880	0.0052	0.0301	0.025	0.030
231.5	*229*	*234*	*-1.7614*	*-1.190*	*0.0392*	*0.1170*	*0.078*	*0.093*
238.0	*235*	*241*	*-1.0795*	*-0.400*	*0.1400*	*0.3446*	*0.202*	*0.241*
244.5	*242*	*247*	*-0.2841*	*0.284*	*0.3897*	*0.6103*	*0.221*	*0.263*
251.0	*248*	*254*	*0.3977*	*1.080*	*0.6600*	*0.8599*	*0.205*	*0.244*
257.5	*255*	*260*	*1.1932*	*1.761*	*0.8830*	*0.9608*	*0.078*	*0.093*
264.0	261	266	1.8750	2.443	0.9700	0.9924	0.023	0.028
270.5	267	273	2.5568	3.239	0.9948	0.9999	0.005	0.006
				Total				1,0

When developing a sizing system, sizes with a frequency greater than 3% or more are considered. Therefore, it is recommended to build a sizing system by foot length with 5 sizes from 231.5 mm to 257.5 mm. It responded to 93.3% of diabetic men's feet by foot length.

Building the Size Structure by Width

According to the foot length in the range of sizes 231.5 ÷ 257.5 mm, the average ball girth of each foot size is determined. The number of sizes by width/ball girth to be set up is shown in Table 6. According to the data in Table 6, the ball girth difference between the smallest size and the largest size is 18.7 mm. With an increase in foot length by 6.5 mm, the average ball girth increase is 4.7 mm. Approximately 5 width sizes are required for each foot length, when using 10 mm ball girth increments.

Table 6: Results of determining average ball girth values (Vb) of foot sizes and number of foot sizes by width

Foot sizes by length, mm	Min of Vb, mm	Max of Vb, mm	Average of Vb, mm	Difference of Vb by length, mm	Selected Vb value, mm	Difference between Max and Min of Vb, mm	Number of sizes by width to be set in 10 mm increments
231.5	212	250	231.4		231	38	3.8
238.0	211	260	235.4	4.0	236	49	4.9
244.5	220	271	240.3	4.9	241	51	5.1
251.0	220	270	245.5	5.2	246	50	5.0
257.5	224	271	250.1	4.6	251	47	4.7

Table 7: Result to calculate foot size by width

Foot sizes by length, mm	Response rate, %, with	
	5 sizes by width	3 sizes by width
231.5	100.0	90.5
238.0	100.0	87.5
244.5	98.1	85.7
251.0	99.5	86.0
257.5	100.0	87.2
Average	99.5	87.4

The results of calculating the number of foot sizes by width with ball girth increments of 10 mm are shown in Table 7.

The use of 5 sizes in width meets up to 99.5% of survey subjects but is not feasible. In the United States, diabetics receive therapeutic shoes manufactured in three sizes by width [20]. Therefore, in this study, three sizes by width in increments of 10 mm were used. It responds to 87.4% of diabetic men's feet. This allows to reduce the number of sizes, and the built-in sizing system will be adapted to the actual shoe production.

Thus, for diabetic men's feet in Vietnam, a foot size system with 5 sizes by length (from 231.5 mm to 257.5 mm) and 3 sizes by width for each size by length should be used. The size system includes 15 sizes that can accommodate over 81.5% of the patient's feet in length and width (Table 8).

Table 8: Diabetic men's foot sizes by length and width

Foot sizes by length, mm	Foot sizes by width, mm		
231.5	221	231	241
238.0	226	236	246
244.5	231	241	251
251.0	236	246	256
257.5	241	251	261

Determining the Foot Parameters for the Size System

To obtain a foot size system in 5 sizes by length (231.5, 238, 244.5, 251, 257.5 mm) and 3 sizes by width, it is necessary to determine the remaining parameters according to the dominant parameters, using the built-in regression equations, that are shown in Table 4. Examples of foot size in length 244.5 mm with 3 sizes by width (A – small, B – medium, C – large) are shown in Table 9.

Table 9: The foot parameters of diabetic men in Vietnam of size 244.5 mm by length with 3 sizes by width

№	Foot parameters	Values by width, mm		
		A	B	C
1	Lf	244.5	244.5	244.5
2	Lmb	180.0	180.0	180.0
3	Llb	159.4	159.4	159.4
4	L5toe	202.4	202.4	202.4
5	Lgot	78.5	78.5	78.5
6	Lla	55.7	55.7	55.7
7	Rmb	95.4	99.5	103.7
8	Rlb	92.2	96.2	100.1
9	Rb	98.6	102.9	107.2
10	Rh	62.6	65.3	68.0
11	C1toe	19.2	20.0	20.8
12	Cmb	31.4	32.8	34.1
13	Cins	51.1	53.3	55.5
14	Cla	57.1	59.5	62.0
15	Vmb	221.1	230.6	240.2
16	Vlb	225.2	235.0	244.7
17	Vb	231.0	241.0	251.0
18	Vw	225.5	235.2	245.0
19	Vins	235.0	245.1	255.2
20	Vh	301.7	314.7	327.8
21	Va	196.4	204.9	213.4

CONCLUSIONS

In this study, the anthropometric characteristics of Vietnamese men's feet with diabetes were investigated. Various types of diabetic foot lesions have been evaluated. Common types of foot injuries are painful feet, swollen ball joints, foot ulcers, dry, cracked skin, and calluses of the feet. The patient's foot deformity is mild. The position of deformity is concentrated in the forefoot. These are the common lesions found in diabetic feet and are consistent with published studies on diabetic foot complications [1-12].

There were significant differences in the parameters according to the width and circumference of the feet of diabetic men and those of healthy men's feet. This suggests the need to develop their own foot sizing system. The foot sizing system has been developed that includes 5 sizes by length (231.5, 238, 244.5, 251, 257.5 mm). Each size by length has 3 sizes by width. This is an important basis for designing shoe-lasts, designing and providing footwear for men with diabetes in Vietnam.

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