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Characteristics of Diabetic Patients with Hallux Valgus Based on the Plantar Pressure and Foot Dimension Measurement

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Abstract This study is a part of a large project of diabetic foot investigation in Chinese Sichuan area, and at least 176 diabetic patients and their counterparts were collected. These samples were gathered for the purpose of investigating the biomechanical characteristics of the diabetic subjects with hallux valgus, and the results of this study could support the development of diabetic protection products. *Methods* This study was design to understand the features of diabetic hallux valgus group on the foot size and plantar pressure distribution, hence, 13 Diabetic patient with hallux valgus, 37 without hallux valgus, and 16 normal subjects with hallux valgus were selected finally to compare, after the randomly selecting and following the excluding criterion. At the beginning of measurement, anthropological variables of each sample, the age (year), height (m) and body weight (Kg) were recorded. Then anthropometric measurement of foot length (mm) and foot width (mm) was conducted by scanning the plantar image. After that, the plantar pressures parameters of mean pressure under ten regions were recorded. Finally, variance differences among these three groups were analyzed by a one way ANOVA test, with significant level equaling to a=0.05. *Results* (1) The width of diabetic hallux valgus group recorded larger than the one of group diabetic without hallux valgus (P=0.065>0.05); (2) The mean pressure under the group of diabetic hallux valgus group showed higher beneath all the foot regions, comparing with the diabetic without hallux valgus group (P>0.05 for all comparisons); (3) In contrast with group of normal subjects with hallux valgus, diabetic hallux valgus group demonstrated a higher pressure value on the all foot regions, except the regions of second and third metatarsal head (P>0.05 for all comparisons). *Conclusions* The diabetic subject with hallux valgus has the following feature: (1) It showed a larger width than the one of group diabetic without hallux valgus, although significant difference only showed in the normal level; (2) A lager pressure value were existing on the group diabetic hallux valgus group under all of foot region, in comparison with that of group diabetic without hallux valgus, and average distinction was more than 20%; (3) The same condition happened on the comparison with normal subjects with hallux valgus and also the difference could reach the average of 20%, while diabetic hallux valgus had a smaller value on the regions of second and third metatarsal head ; (4) A special attention need to be paid to this group in correct footwear wearing in order to avoiding the foot damage.

Keywords*:* diabetic foot; hallux valgus; foot width; plantar pressure;

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Introduction

The hallux valgus, which usually happening in diabetes mellitus patients, is also considered as a kind of deformity in the first metatarsal head. There are many reasons for the development of hallux valgus in this group, but one of the possible explanation was that as the constant arise of blood glucose causes the ratio of protein in the ligament reduction which used to support the bone and foot structure in metatarsal area, then the loose of protein can results in the lower flexibility and strengthens in ligament, and lead to the development of hallux valgus [(1) (2)]. Regarding to the plantar pressure distribution under diabetic patient, literatures from Shaw JE et.al [(3)]and Cavanagh PR et.al [(4)] reported that a higher pressure value, longer contact time and larger value of force-time integral were recorded under the diabetic foot.

Since the foot structure determined plantar pressure distribution, and based on the results from Bryant A et.al [(5)], the hallux valgus can severely interrupt the structure of forefoot of the group without diabetes mellitus. Undoubtedly hallux valgus in the diabetic group could also affect the plantar pressure distribution, unfortunately, seldom had literatures been reported on the plantar pressure characteristics of diabetic hallux valgus patients. Theoretically, the deformity deviates the position of first metatatsophalangeal joint medially, and increases the size of the forefoot. Then the shoe with normal width is no longer safety for the diabetic hallux valgus group to wear, for that the augment of foot size will cause the more severe friction happening on the places of deformity, which could lead to the strains of this position, even to the ulceration. Fortunately, right now shoe's function had been deeply evaluated [(6)] and recognized as an effective way to attenuate the pressure concentration and provide right structure, and prevent the happening of foot trauma and ulceration. Therefore, prior to develop protection strategy, it is better to understand the major biomechanical features of diabetic hallux valgus patients.

This study is a pilot research on the aspect of how the hallux valgus affects ether the size or the plantar pressure of the diabetic group. Therefore, the aim of this study was to collect the foot anthropometric and plantar pressure data of the three groups, they were the diabetic hallux valgus (DMHV), diabetic without hallux valgus (DMwHV), and normal hallux valgus (NHV). According to the literature, there are three hypotheses in this study: 1 DMHV may have a larger foot width as the reason of deformity of hallux valgus, comparing with DMwHV; 2 comparing with NHV, because of diabetes mellitus, DMHV could express a larger plantar pressure volume, such as conclusions made by Cavanagh PR [(4)]; 3 based on the report from Bryant A [(7)], the planter pressure value under the DMHV dominates that of beneath the DMwHV.

This study is a part of a large project of diabetic foot investigation in China Sichuan area. At least 176 of the total samples were collected, including 81 diabetic patients, 95 subjects without diabetic. The protocol of this study was approved by the Human Research Ethics Committee of Sichuan University.

Materials and method

Methods

Subjects

All subjects were collected in Endocrine Section of West China Hospital of SCU and Sichuan University. They were divided into three groups: DMHV, DMwHV and NHV. Aims of this research were explained and informed consents were given by them.

In this study, all the hallux valgus angle (HVAwas determined by the plantar scanning, the method

was described as below: the HVA is constructed by the inside tangent passing the swell of inside heel and 1st metatarsaphalangeal joint of the foot and the tangent formed by prominence of hallux and 1st metatarsaphalangeal joint (See Fig.1). HVA equaled to 15 degree or larger was selected as criterion for hallux valgus. Other criterions were shown in the table.1.

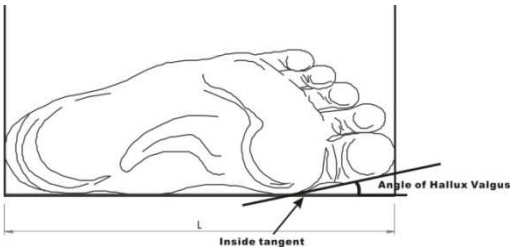


Fig. 1 the schematic of Angle of hallux valgus

Tab. 1 the exclude criterions for all subjects

Group	Exclude criterions
DMHV	*without definite diabetes mellitus diagnoses, with former ulceration, with former orthopedic operation, with the angle of hallux less than 15 degree*
DMwHV	*without definite diabetes mellitus diagnoses, with former ulceration, with former orthopedic operation, with the angle of hallux larger than 15 degree*
NHV	*With diabetes mellitus or other metabolic disease, with foot pathology, with former orthopedic operation, with the angle of hallux less than 15 degree*

Finally, 104 subjects meet these requirements. Among these qualified subjects, a random selection by the SPSS (SPSS for Windows v. 16.0; SPSS Inc, Chicago, USA) was conducted in this study. The final samples' anthropological information shows in Tab.2.

Sforza et al [8] suggested high symmetry of individuals demonstrate between left and right feet from one individual and as a high correlation will exist in whatever measurements were taken and essentially had the same effect as the foot being measured twice Landorf [9] and Menz [10]. Both feet used for analysis will interrupt the true relationship between variables, as this reason, right foot data only was taken from each participant in this study. Another influence factor in this study was the gender influence, while according to the variance analysis in this study, there was no significantly difference ($p>0.05$) existing in the both female and male for all parameters. It was same as the results of Bennett P [11].

Tab. 2 the anthropological information of selected subjects

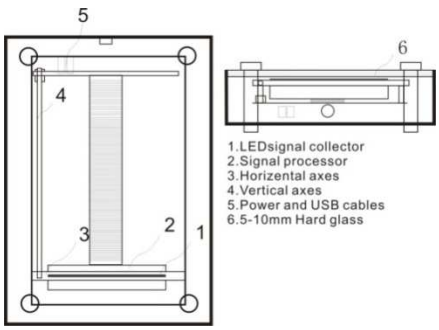
Group	Cases(right foot)	Mean age[year]±SD	Mean BMI ±SD	Mean angle of hallux[degree]±SD
DMHV	13	64.88±6.73	23.83±2.79	21.98±5.07 **, a,
DMwHV	37	64.33±8.02	23.19±2.74	7.44±3.48 **,a, b
NHV	16	66.31±8.55	22.50±2.87	21.81±7.07 **, b

DMHV: diabetic hallux valgus; DMwHV: diabetic without hallux valgus; NHV: normal hallux valgus subjects;
**,a:significant between group of DMHV and DMwHV, p=0.000<0.001;
**,b:significant between group of DMwHV and NHV, p=0.000<0.001;

Plantar image scanning

Plantar image scanning system (FOS-002; Sichuan University work unit, Chengdu, P.R. China) comprises a harden glass plate (width, 60cm; length, 50cm; height, 8cm) on the surface holden by four steel poles, around which there exist five light-shading plates(two plates: width, 17cm; length, 60cm; height, 1cm. two plates: width, 17 cm; length, 50cm; height, 1cm. one plates: width,50cm; length, 60cm; height, 1cm). A plate (width, 40cm; length, 30cm; thick, 1cm) is suspended on the height of 10cm in the box as scanning surface. On this surface a modified scanner (Microteck 3800; MicroTeck, Taiwan, China) is fixed(see Fig.2). Patients firstly were asked to stand on the harden glass, with body weight distributing equally to the two feet. The light of scanner passed through the glass and captured plantar image, then the CCD processor was applied to transfer the reflected light to the electric signal, at last these signal was transmitted to the computer and analyzed by software of CorelDraw (v12; Coral Corporation, USA). The error of this instrument was 0.05mm. Successful five pair of footprints of each patient was scanned [12].

Fig. 2 the schematic of plantar image scanning system



Plantar pressure measurement

An EMED-at (Novel Electronics, Novel gmbh, Munich, Germany) capacitance mat transducer system, with sensor dimension of 385×226mm, mounted flush with the floor surface at the centre of 5m raised walkway, was used for Plantar pressure measurement. The platform comprises 1740 individual sensors at a density of 2 /cm2, and requires data at a sampling rate of 25Hz. The reliability of plantar pressure measurements were testified by Cavanagh PR et al [13], and the software system were used in analyzing the data. At the beginning, each subject was allowed to familiarize with the testing procedure by walking in their comfortable speed several times. Then the subjects were guided

not to attention the target, but just look forward and walk straight. Each subject has the data collected from both left and right foot for successful five times [12].

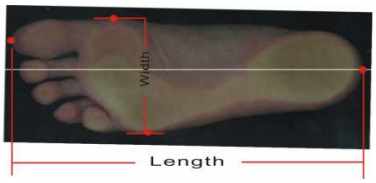
Data processing

The schematic in Fig.3 shows how the foot length and width were measured by the CorelDraw. A basic horizontal line was drafted through the lowest point of heel judged by eyes, and made the central axis be vertical with horizontal line, where the central axis is going through the lowest point of centre of heel and the middle of 2nd toe. The foot length was defined as the longest part of the sole, and the width was as calculating the width of two perpendicular lines drawing from the first to fifth metatarsophalangeal joint.

For calculating the parameters of each position, the foot of each subject was divided into ten regions or masks by applying the EMED Automask software (Novel Electronics, Novel gmbh, Munich, Germany). The ten regions include big toe (T1), second toe (T2), third to fifth toe (T345), the first to fifth metatarsal head (MTH1-MTH5), mid foot (MF) and hind foot (HF) (See Fig.4). About hind foot region, it was discarded in this study for that his study mainly focusing on the changes happening on the mid and fore foot. The parameters of mean pressure (Kpa) underneath each ten area were collected.

Statistical analysis

First of all, the average conducted among the five measurements of individual, then within the data of all individuals. After that a normal distribution test for each parameters were carried with P-P plot from SPSS software (SPSS for Windows v. 16.0; SPSS Inc, Chicago, USA). At last, a one way ANOVA test with levene test and LSD was conducted to compare the distinction of variances among these three groups. All the analysis were depended on the significant level of a= 0.05.



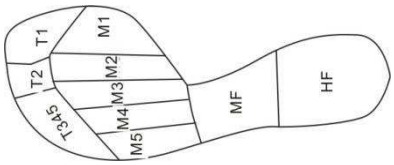


Fig 3 Plantar dimension analysis schematic diagra Fig 4 ten regions of plantar pressure measurements

Results and discussion

Results

According to the P-P plot test, all of variables followed normative distribution, so all of the parameters were fit for further analyses.

Foot size

DMHV had a larger foot width, according to the compare with DMwHV group (Tab.3).

Tab. 3 relative width of three groups

Group	Cases(N)(Right feet)	width (mean)	Relative width (SD)
DMHV*,a	13	95.17	4.43
DMwHV*,a	37	91.65	6.17
NHV	16	96.92	5.68

*,a:significant between group of DMHV and DMwHV, p=0.065>0.05;

Plantar pressure parameters

The pressure value recorded in the group of DMHV were larger than that of DMwHV under all of foot regions(P>0.05 for all comparisons), at the same time, the distinction between the two groups showed more than 20%, apart from the region of MTH1 , MTH4 and MF(T1(24%) , T2 (65%) , T345(34%), MTH2(20%), MTH3(20%) and MTH5(29%)). In contrast with group of NHV, DMHV demonstrated a higher pressure value on the all foot regions as well, except the regions of second and third metatarsal head(P>0.05 for all comparisons). Their differences also could reach the level of 20%, such as MTH1(21%), MTH2(-38%), MTH5(57%) and MF(58%), where -38% distinction indicated that the pressure of DMHV was lower than that of NHV.(Tab.4)

Tab. 4 relative mean pressure value under nine regions of three groups

		N	Mean	SD
bigtoe	DMHV	13	146.54	85.863
	DMwHV	37	117.57	49.084
	NHV	16	144.69	125.120
MH1		13	115.00	59.617
		37	112.70	44.089
		16	94.69	52.201
MH2		13	125.77	88.125
		37	104.73	81.266
		16	171.88	103.455
MH3		13	148.08	91.254
		37	122.57	83.055
		16	154.06	97.095
MH4		13	101.15	47.353
		37	98.11	84.149
		16	89.38	43.277
MH5		13	152.31	93.689
		37	117.70	85.209
		16	97.81	56.154
midfoot		13	74.23	62.611

	37	66.76	37.624
	16	46.88	21.747
toe2	13	68.85	87.158
	37	41.49	24.913
	16	55.94	27.762
toe345	13	67.69	75.294
	37	50.14	31.830
	16	53.44	24.747

Discussion

The method of plantar image scanning was adopted in this study, although it was considered to be simple, fast and easy to analysis, it is not so accurate with that of X-ray measurement, because according the image from the X-ray, researcher could explicitly recognize the position of metatarsal head, so as to the hallux valgus angle [5]. However, the method of X-ray was reported as costly and expensive, it is considered not fit for the larger group measurement. The foot postion for analysis of our measurement is proved by the standard committee of TC/137, and widely used in their terminology definition. So, an empirical HVA was analysis in this study.

The development of hallux valgus usually accompanied with the change of foot structure [14]. In the viewpoint of anatomical, hallux valgus deviates the position of MTH1 towards medially and makes the position of hallux shift laterally. This phenomenon was testified by significant difference in angle of hallux in DMHV group, in comparison with group of NHV and DMwHV. Moreover, the width differences between DMHV and DMwHV were exsiting, but only a normal significant level was found. Nevertheless, this result confirmed our hypothesis.

It is necessary to discuss the importance of width of foot in wearing shoes, because it determines the shoe's girth and shoe's safery or comfort. Wearing the ill-shoe, in some extent, wearing the right width for general people, will become a risk factor and threat health of diabetic hallux valgus foot. Maciejewski ML et.al [6] conducted a review which studies the efficiency of footwear in preventing reulceration of DM patients, and found that there was statistically significant protective effect on ulceration from therapeutic footwear. For the better protect for the DMHV patients, the clinician have to evaluate the width of patient's foot and the width of their footwear, avoiding the hurts caused by wearing inappropriate shoe.

In term of plantar pressure distribution, DMHV was higher than that of DMwHV and NHV in almost foot regions, this result was similar with the found from Bryant A [7], who's study focused on the hallux valgus group without diabetes mellitus. It is a pity that only lower significant level ($P>0.05$) could be gained between our comparisons. For the reason, it could attribute to the lack of sufficient hallux valgus samples. At the beginning of this study, 176 samples including diabetic patients and control samples were measured, though, after randomly selecting as well as excluding criterion, finally 66 people comprised by 29 hallux valgus samples and 37 normal foot samples were left and fit for further analysis. What's more, another probability was that the degree of deformity in DMHV was

not so severe that could turn over the traditional way for plantar pressure distribution. In another word, DMHV also followed the normal rules the same as the DMwHV and NHV.

Although, lower significant differences were lacking in this study, the distinctions existing among groups could provide us some basic information about the feature of diabetic patients with hallux valgus. Between DMHV and DMwHV, the main differences happened on the fore foot, such as MTH regions and toe areas; while between DMHV and NHV, distinction appeared on the mid and fore foot, such as MF and MTH regions.

Since this study was on the first step to understand the biomechanical feature of diabetic patients with hallux valgus, many limited factor in this study such as the ignorance of the analysis of hind foot and the biomechanical features in the context of wearing shoe. Further investigation will be focused on the interface between footwear and foot. Walking in shod is more practical in everyday's life than bared foot, and when walking with unfit footwear, the unfitted footwear size may change the loading pattern under foot by augmenting frictions on the medial, lateral side and sole of foot. It is assumed that a increasing of pressure value could appear. Therefore, further study need to be concerning on the insole pressure, medial and lateral pressure measurement of DMHV group.

Conclusions

The diabetic subject with hallux valgus has the following feature: (1) It showed a larger width than the one of DMwHV, although significant difference only showed in the normal level; (2) A lager pressure value were existing on the group DMHV under all of foot region, in comparison with DMwHV, and average distinction was more than 20%; (3) The same condition happened on the comparison with NHV and also the difference could reach the average of 20%, while DMHV had a smaller value on the regions of second and third metatarsal head; (4) A special attention need to be paid to this group in correct footwear wearing in order to avoiding the foot damage, as the reason of their larger foot width and a varied gait ways.

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