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Comparative analysis of dynamic angle characteristics of hallux valgus and design suggestions of orthopedic shoes

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ABSTRACT. *Using the current advanced plantar pressure testing technology in the field of footwear, the plantar pressure data of hallux valgus foot group and normal foot group during walking were collected, and the plantar dynamic parameters of walking between the two groups were compared. The data were analyzed and processed by software, and the changes of the dynamic parameters of the normal lower limbs caused by hallux valgus of the foot were discussed, and the results showed that hallux valgus had an effect on human beings the influence of foot pressure distribution and transition. To provide a theoretical basis for the design of correction shoes for hallux valgus patients.*

KEY WORD: *Hallux valgus, plantar pressure, locus of pressure center, comparative study*

1. Introduction

Foot is an important part of human body. It is an important functional structure to support human body weight and maintain body balance. Among many foot diseases, hallux valgus is considered to be the most common one at present. Because of the occurrence of hallux valgus, not only the appearance of wearing shoes is affected, but also the serious hallux valgus will cause the change of bone position and affect the physical and mental health of human body.

Research on hallux valgus is a research direction to effectively alleviate foot diseases encountered in the process of modern people wearing shoes. In addition to X-ray technology, plantar pressure testing technology is more common in the research on hallux valgus in recent years, and the applicability of experimental data is strong. Based on the dynamic analysis of the plantar pressure characteristics of hallux valgus, this paper puts forward some suggestions for the design of orthopedic shoes, which provides a theoretical basis for the design of orthopedic shoes for hallux valgus patients [1].

2. Subjects and methods

2.1 Subjects

According to the evaluation standard of hallux valgus, the first toe and the first metatarsal were determined to have a relative deviation angle of $\geqslant$ 15 ° by the ray method. Finally, hallux valgus group and normal group were established. Finally, 15 subjects were selected from each group. In the hallux valgus group, the average age was 22.05 ± 0.8, the average weight was 61.3 ± 8.2, the average height was 171.3 ± 4.2, and the average foot length was 24 ± 1.3. In the normal group, the average age was 22.7 ± 0.7, the average weight was 59.1 ± 5.8, the average height was 169.5 ± 3.2, and the average foot length was 25 ± 0.8. In order to facilitate the elaboration, the hallux valgus group and the normal group are respectively defined as the hallux valgus group and the normal group.

2.2 Experimental method

(1) Experimental instruments

There are two main types of instruments used in the plantar pressure test under the condition of barefoot: the first is the apparatus used for the evaluation and test of hallux valgus test objects (X-ray of hallux valgus and normal foot test objects), the second is the plantar pressure test equipment, including the plantar pressure test track, plantar pressure plate and plantar pressure analysis software.

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(2) Experiment preparation

The subjects wore black tights and bare feet (light socks can be worn). The weight and height of the subjects were measured by ultrasonic height and weight meter. The arch coefficient of the subjects was measured by pressure plate. The basic information of the subjects was obtained. The subjects were screened by X-ray test. Before the test, two groups of subjects were required to walk on the test track for 5 minutes at a normal pace of 1.36M \ s in barefoot condition.

(3) Experiment process

To collect plantar pressure of normal foot in advance, the subjects are required to walk at one end of the runway at a normal personal walking speed of 1.36M \ s. Listen to the experiment start command, walk on the test track, each subject respectively collects the foot pressure data of 10 groups of repeated 5 times, and obtains the complete left and right foot gait dynamics information of each subject in 5 groups. The test process of hallux valgus group was the same as that of the normal foot. The plantar pressure data of each subject were collected respectively, and the width and length of the plantar print were measured by the plantar pressure test equipment with the method of manual adjustment. The preliminary data screening was carried out to complete the pressure division of each part of the plantar.

2.3 Definition and selection of experimental indicators

The experimental index of this paper is mainly related to the plantar pressure distribution, which includes the plantar pressure test equipment to collect the pressure distribution information of the plantar contact with the ground. According to the difference of foot pressure distribution between the experimental group and the normal group, the peak index of plantar pressure: (N), transitional displacement index of plantar pressure center locus:(mm), plantar pressure index:(N/cm^2), were selected. According to the definition of different indicators, according to the plantar pressure analysis system automatic zoning function, combined with manual selection of zoning, the plantar region is divided on the basis of bone identification of plantar bone. Firstly, the whole plantar was divided into three areas: heel area, arch area and forefoot area. The information of these three areas reflected the overall distribution trend of plantar pressure and the type of arch in the experimental group. At the same time, this study needs to divide the plantar into ten anatomic areas, which are the inside and outside of the heel. H1 and H2 on the inside of the heel, MF on the arch, M1 on the first metatarsal bone, M2 on the second metatarsal bone, M3 on the third metatarsal bone, M4 on the fourth metatarsal bone and M5 on the fifth metatarsal bone. The first toe area is T1, and the second to fifth toe areas are t2-5. Through the above division of plantar stress area, reflect the distribution of plantar pressure and the progressive trend of pressure, which is conducive to the collection and standardized processing of experimental data [2].

According to the bone mark points of plantar bone, different colors are used to replace the plantar area, and the pressure distribution data analysis can be carried out, and the distribution trend of the data can be preliminarily counted. (as shown in Figure 1-1: Location map of left and right foot zones)

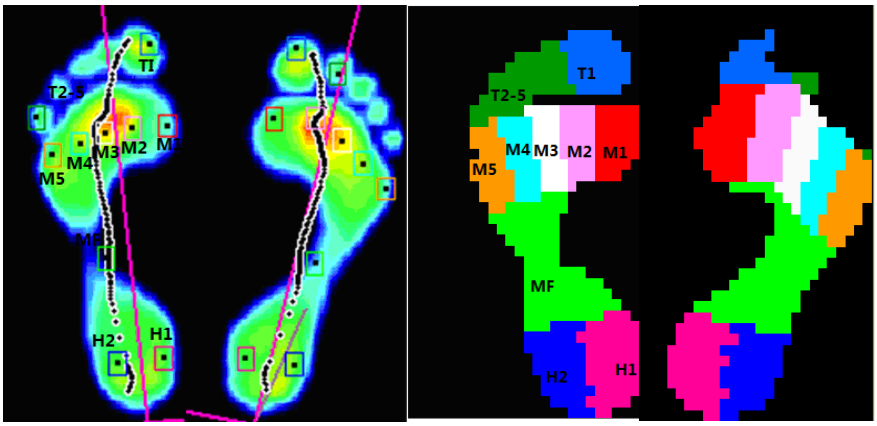

Fig.1 Left and right foot zoning map

2.4 Experimental data processing

The division of plantar pressure among different experimental subjects is the premise of obtaining the pressure distribution of plantar bone marker area correctly. (as shown in Figure 1-2: plantar pressure zoning map)

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SPSS11 statistical software was used to test the single factor variance of data and analyze the significance of pressure distribution in different areas. At the same time, the transition trend of plantar pressure and the dynamic parameters of foot supporting were analyzed, and the differences in the center track transition of plantar pressure, the concentration of plantar pressure distribution and the influence of foot movement characteristics between the hallux valgus group and the normal group were compared [3][4],forming the reference data base for the improvement of shoe design.

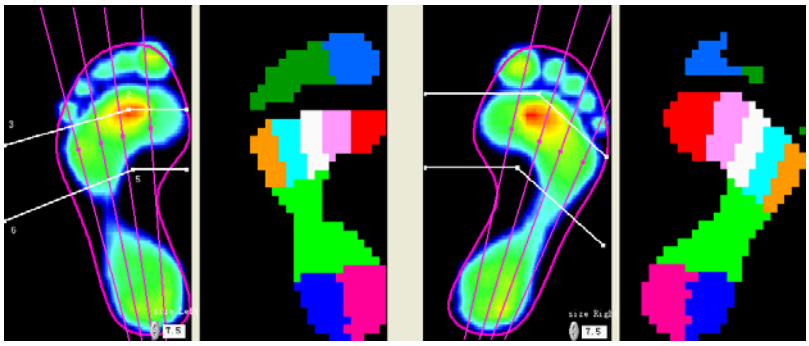

Fig.2 Plantar pressure zoning map

2. Comparative analysis of research results

2.1 Comparative analysis of the transition trend of plantar pressure center track

The locus of plantar pressure center is a virtual line of force center points which is impacted by the ground pressure when the foot touches the ground. The locus of plantar pressure center is the locus of the center of ground force in the stage of plantar landing during the period of plantar support, and the changing route can reflect the trend of the movement and turnover of the foot when landing. Through the analysis of the locus of the plantar pressure center, it is possible to analyze the turnover of the foot without image testing technology, and to understand the relationship between the interaction of the foot and the ground in the process of landing. It is of great significance to evaluate the influence of hallux valgus on the movement of the foot, especially the influence of the left and right supporting effect of the foot when the structure of the forefoot and metatarsal bone changes Ring. In the experiment, the lateral displacement and the longitudinal displacement of the center track of foot pressure of two groups of experimental objects are analyzed and compared.

The experimental results are as follows: lateral displacement (x): 28.24 ± 5.2 (mm) in hallux valgus group,35.15 ± 6.4 (mm) in normal group, $P < 0.05$; longitudinal displacement (y): 208.20 ± 7.8 (mm) in hallux valgus group, 211.2 ± 5.5 (mm) in normal group, $P > 0.05$.

Through the test of the plantar pressure plate, the system automatically calculates the lateral and longitudinal displacement of the plantar pressure center track, and through the comparison of the experimental objects in the hallux valgus group and the normal group, the influence of hallux valgus on the lateral and longitudinal displacement of the plantar pressure center track is determined.

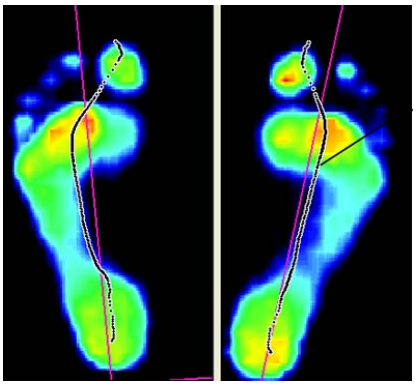

Fig.3 Experimental object plantar pressure center track sketch map

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(1) Comparative analysis of the average lateral displacement of the pressure center of the foot in the hallux valgus group and the normal group

Theoretically, according to the understanding of foot anatomy, the average lateral displacement of the locus of plantar pressure center depends on the width of the foot. In addition, because hallux valgus causes the first metatarsal bone of the forefoot to move outward, it is bound to increase the width of the forefoot. The average forefoot displacement of hallux valgus experimental subjects should be greater than that of the normal group, but in the actual comparison, it is found that the average lateral displacement of the foot pressure center locus of the experimental subjects in the hallux valgus group is smaller than that of the normal group. Table 2-1 experimental data shows that the indexes of the average lateral displacement of the two groups of experimental subjects in the foot pressure center track are respectively: hallux valgus group (28.24 ± 5.2) mm, normal group (35.15 ± 6.4) mm, $P<0.05$, with significant difference. It shows that the increase of the width of the forefoot and metatarsophalange does not result in the increase of the force on the first metatarsophalangeal joint. The change of the displacement of the first metatarsophalangeal joint is only the change of the shape and structure, but the track of the pressure center of the sole of the foot becomes smaller, which results in the damage to the force mode of the forefoot of the normal foot type, and the force on the pedal extension of the foot is affected. This conclusion is significantly different from the observed width of the forefoot in hallux valgus patients. Combined with the analysis of the stress characteristics of the plantar pressure, the first metatarsophalangeal joint is only a structural position change. In fact, the first metatarsophalangeal joint is not substantially involved in the support mode of the plantar to the body weight. The plantar foremetacarpal metatarsal bone is affected by the change of hallux valgus. The possible mechanism is that it shares part of the first metatarsophalangeal joint due to the compensatory effect of the bones in different parts of the foot the supporting function of bone makes the whole landing time stable and the gait symmetrical and normal. However, the change of mechanical mechanism needs a lot of experimental research.

(2) Comparative analysis of the longitudinal mean displacement of the pressure center locus of the plantar in the hallux valgus group and the normal group

There was no significant difference in the mean longitudinal displacement of the pressure center of the foot between the hallux valgus group and the normal group through the test, analysis and comparison. The experimental data in table 2-1 showed that: the hallux valgus group (208.20 ±7.8) mm, the normal group (211.2 ± 5.5) mm, $P > 0.05$. The main reason why there is no significant difference in the locus of plantar pressure center is that the foot length of the test object is relatively close, that is,the center line of the foot in the longitudinal force is produced by the contact part of the foot length. The results showed that the images caused by the structure of the forefoot metatarsals in the hallux valgus group did not promote the change of the mean longitudinal displacement of the plantar pressure center track, and the longitudinal displacement of the plantar pressure center track was not significantly related to the change of the position of the forefoot metatarsophalangeal joint. The locus of plantar pressure center is directly related to the natural foot length of human body, that is, the longer the locus of plantar pressure center is, the shorter the locus is. In similar studies, some researchers also analyzed the relationship between the longitudinal displacement of the foot pressure center track and the wearing stability of footwear products [5], which can be understood as: the larger the longitudinal length of the foot pressure center track, that is, the longer the foot, the larger the contact area with the ground, the higher the stability. In this study, we did not judge the stability of the difference of the longitudinal pressure center locus of the human sole,only discussed the influence of the metatarsophalangeal joint displacement caused by hallux valgus on the pressure center locus.

2.2 Comparative analysis of dynamic parameters of foot support

Different from the track of foot pressure center and the time of foot landing, the dynamics of foot support mainly refers to the effect of the impact force on the foot in each area of the foot in the stage of single support. Because the weight of the test object is often larger in height and foot length, in fact, the strength allocated to the unit area of the foot has not changed significantly.

In this paper, the comparison of dynamic parameters of the foot supporting is mainly to analyze the influence of the position of the bone structure of the forepaw and metatarsal on the changes of the force on the plantar area. Compared with the distribution of foot pressure, the dynamic parameters of supporting the ground of the foot, especially the changes of the bone structure of the forefoot caused by hallux valgus, will inevitably affect the pressure dispersion effect of the whole foot in the process of contacting the ground. Through the plantar pressure test, the plantar was automatically divided into ten anatomic areas, and manually adjusted according to the bony mark points. The mean force of different areas of the plantar in the whole single support stage was collected, and the difference of pressure distribution between the experimental subjects of hallux valgus group and the normal

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group was analyzed and compared, so as to judge the pressure of hallux valgus on the plantar pressure of human body The influence of stress on cloth area.

The experimental results are as follows:HL,hallux valgus group30.1±5.6(N/cm^2),normal group27.7±6.9(N/cm^2),P>0.05;HM,hallux valgus group27.4±4.7(N/cm^2),normal group30.1±8.5(N/cm^2),P>0.05;MF,hallux valgus group35.2±2.3(N/cm^2),normal group33.7±4.5(N/cm^2),P>0.05;M1,hallux valgus group9.1±3.5(N/cm^2),normal group12.5±5.5(N/cm^2),P>0.05;M2,hallux valgus group24.2±4.4(N/cm^2),normal group13.7±5.7(N/cm^2),P<0.05;M3,hallux valgus group34.4±2.9(N/cm^2),normal group15.6±7.2(N/cm^2),P<0.05;M4,hallux valgus group10.5±6.4(N/cm^2),normal group9.8±2.4(N/cm^2),P>0.05;M5,hallux valgus group11.2±1.7(N/cm^2),normal group8.5±2.5(N/cm^2),P>0.05;T1,hallux valgus group29.2±4.5(N/cm^2),normal group8.9±2.9((N/cm^2),P<0.01;T2-5,hallux valgus group11.9±3.6(N/cm^2),normal group9.9±2.8((N/cm^2),P>0.05.

According to the previous partition method, through the test, data analysis and comparison of plantar pressure distribution, the peak pressure distribution data of ten areas of plantar were obtained. There were significant differences in the pressure release between the hallux valgus group and the normal group in the second metatarsal bone, the third metatarsal bone and the first toe, but there was no significant difference in the peak pressure in other areas of the foot, and the areas with significant differences in the peak pressure of the two groups covered the hallux valgus bone position change area. According to the analysis of the main reasons for this result, as the anatomical structure of the forefoot changes under the influence of hallux valgus, and the hallux valgus situation further worsens with the increase of walking and improper wearing of shoes and other reasons, considering that the lateral displacement of the track of the pressure center of the sole in the forefoot in the hallux valgus group is smaller than that in the normal group, the pressure of the sole at the first metatarsal is judged The peak value did not increase significantly, but the corresponding peak pressure appeared at the second metatarsal and the third metatarsal, which was consistent with the results measured in this study. The peak pressure of the second metatarsal was (24.2±4.4) N/cm^2 in the hallux valgus group and (13.7±5.7) N/cm^2 in the normal group (P<0.05). At the third metatarsal site, the peak pressure of hallux valgus group was (34.4±2.9)N/cm^2, and that of normal group was (15.6±7.2) N/cm^2, P<0.05. There was also a significant difference between the two groups. The abnormal distribution of peak pressure at the second and third metatarsals is one of the main reasons for the further deterioration of hallux valgus. The distribution of plantar pressure data is consistent with the result of lateral displacement of pressure center track.

Moreover, compared with the normal group, the experimental subjects in the first hallux valgus group showed a significant increase in peak pressure, in which the peak pressure data of T1 in the hallux valgus group reached (29.2±4.5) N/cm^2, while that in the normal group was only (8.9±2.9) N/cm^2, P < 0.01. There are significant differences between the two groups. The main reason is that the pressure of the second and the third metatarsals is not only over concentrated, but also over pronation of the first toe. That is to say, the first metatarsophalangeal joint is the axial center of the toe. Combined with the abnormal term of plantar pressure distribution, it can be concluded that the important difference of plantar pressure distribution among the subjects of hallux valgus experiment is mainly caused by the excessive pronation of the first toe and the concentration of pressure under the second and third metatarsals. At the same time, due to the binding of toe shape, the joint action promotes the deterioration of hallux valgus.

In the walking process of the normal foot and hallux valgus foot, the first toe has a significant pronation trend with respect to the first metatarsal bone, while the first toe of the normal foot basically presents a straight feature in the walking process. Further analysis showed that the relative internal rotation and the first metatarsal bone formed a reverse movement at the first metatarsophalangeal joint. Combined with the distribution of plantar pressure, the stress of the first metatarsophalangeal joint was significantly reduced in hallux valgus patients. It is concluded that the opposite twisting force of the foot at the first metatarsal bone of the forefoot is another key factor to cause the hallux valgus of the human body. It is an important hint for the design of footwear products specially for the patients with hallux valgus, that is, how to limit the excessive pronation of the first toe of the patients with hallux valgus is an important means to effectively inhibit the further deterioration of hallux valgus.

3. Design suggestion of hallux valgus orthopedic shoes

In this paper, we compared and analyzed the transition trend of plantar pressure center track and the dynamic parameters of foot support in hallux valgus group and normal group. According to the experimental data and analysis results, there is a significant difference between the hallux valgus group and the normal group. The analysis results obtained in this paper provide suggestions for the design and application of orthopedic shoes for hallux valgus patients.

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First, according to the characteristics of the increased lateral displacement of the pressure center track of the sole of the hallux valgus test object, it is suggested that the design of the forefoot metatarsophalangeal joint circumference of the last should be taken into account in the design of its special correction shoes, and the design of the too large or too small metatarsophalangeal joint circumference can not effectively solve the problem of wearing comfort and correction, and the application of elastic materials in the interior should be taken into account.

Second, we should fully consider the influence of the upper on the first metatarsal binding force, how to reduce the binding effect of the upper through the structural change, to limit the toe valgus of the experimental object of hallux valgus, and improve the occurrence of excessive binding force of the upper at the same time.

Third, in the design of footwear for patients with hallux valgus, we should not pursue one-sided restraining the correction structure design of the first toe. At the same time, we should fully realize that the excessive internal rotation of the first toe is also one of the important reasons for hallux valgus. Therefore, in the selection of correction structure, we should select elastic material with viscosity, on the one hand, it can restrain the adduction of the toe and improve it effectively the trend of internal rotation.

Fourth, the opposite torsion of the foot at the first metatarsal bone of the forefoot is another key factor that causes the hallux valgus of the human body. It gives an important hint for the design of footwear products specially for the patients with hallux valgus. That is, how to limit the excessive pronation of the first toe of hallux valgus patients is an important means to effectively inhibit the further deterioration of hallux valgus.

4. Conclusion

In this paper, young students are taken as the experimental subjects, and based on the dynamic research, the plantar pressure characteristics of hallux valgus patients in walking state are analyzed by plantar pressure test. The main indexes are the excessive trend of plantar pressure center track, the dynamic parameters of the foot supporting the ground, etc., which are compared with the plantar pressure of normal people, involving human biomechanics, materials science and footwear design Science and other disciplines. To study and discuss the changes of dynamic parameters of normal lower limbs caused by hallux valgus in young female students. At the same time, in view of the current situation of scientific and technological innovation in the footwear industry, the research and design of hallux valgus shoes will also supplement the categories of footwear, drive the design field to carry out comfortable and functional footwear design based on the research of human mechanics, and promote the transformation and upgrading of the industry.

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References

[1] Zhang Wei (1998). Application of plantar pressure analysis in foot diseases [J]. Chinese Journal of orthopaedic surgery, no.3, pp.78-79.
[2] Luo Jiong (2007). Application characteristics of plantar pressure distribution measurement technology [J]. China tissue engineering research and clinical rehabilitation, no.9, pp.75-76.
[3] Tang Rongguang (1994). Measurement of static and dynamic pressure distribution of the foot in normal people [J]. Chinese Journal of biomedical engineering, no.2, pp.45-46.
[4] Yuan Gang, Zhang muxun, Wang Zhongqin (2004). Analysis of plantar pressure distribution and its influencing factors in normal people [J]. Chinese Journal of physical medicine and rehabilitation, no.3, pp.12-13.
[5] Sun Tianhui (2015). Effect of sole structure on dynamic pressure and landing characteristics of sole [J]. China leather, no.14, pp.78-79.