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Comparative Analysis of the Position Characteristics of Hallux Valgus Based on Kinematic Angle and Design Suggestions of Orthopedic Shoes

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ABSTRACT. *Using X-ray and plantar pressure test technology, the plantar pressure data of hallux valgus foot group and normal foot group were collected, and the foot landing time and foot support period turnover characteristics were analyzed. The differences of foot landing time, foot support period turnover between hallux valgus group and normal group were compared, and the influence of foot movement characteristics was also analyzed According to the analysis and processing, the reference data base for improving the design of hallux valgus orthopedic shoes is formed. The design suggestions of hallux valgus orthopedic shoes are put forward.*

KEYWORDS: *Hallux valgus, Plantar pressure, Landing time, Comparative analysis*

1. Introduction

Hallux valgus is one of the most common foot diseases, which not only affects the appearance of shoes, but also causes the change of bone position and affects the physical and mental health of human body. In addition to X-ray technology, plantar pressure testing technology is more common in the research of hallux valgus in recent years, and the applicability of experimental data is strong. Based on the kinematic analysis of the landing time of hallux valgus foot and the flipping characteristics of the foot during the supporting period, this paper puts forward suggestions for the design of orthopedic shoes, which provides a theoretical basis for the design of professional orthopedic shoes suitable for hallux valgus patients [1].

2. Subjects and Methods

2.1 Subjects

In this study, the subjects were young college students. The first toe and the first metatarsal were judged by the ray method, and the patients with hallux valgus were determined. The hallux valgus group and the normal group were established. See Table 1 for the basic information of the subjects.

Table 1 Experiment Object Basic Information Table

	Number of people	Age	Weight	Height	Foot length
Hallux valgus group	20	21.15±0.6	58.3±7.3	172.2±3.1	24.1±1.3
Normal group	20	22.6±0.8	59.1±5.6	170.5±4.2	25.4±0.8
P value		>0.05	<0.05	>0.05	>0.05

2.2 Experimental Method

2.2.1 Experimental Instruments

There are two kinds 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 apparatus and equipment for plantar pressure test, including the plantar pressure test track, plantar pressure plate and plantar pressure analysis software.

2.2.2 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.

2.2.3 Experiment Process

The foot pressure experiment of normal group is carried out in advance. The subjects are required to walk on the test track at one end of the track according to their normal walking speed of 1.36M \ S. each subject is required to collect 10 groups of foot pressure data for 5 times respectively to obtain complete left and right foot gait dynamics information of 5 groups of subjects. The test process of hallux valgus group was the same as that of the normal group. The plantar pressure data of each subject were collected respectively 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

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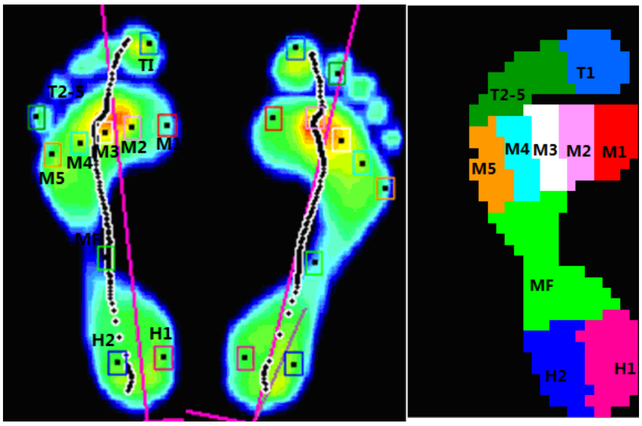
distribution, which includes the plantar pressure test equipment to collect the pressure distribution information of the plantar contact with the ground. According to the difference of foot type pressure distribution between the experimental group and the normal group, the peak indexes of plantar pressure were selected: n, N / cm^2. 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: medial H1 and lateral H2 of the heel; arch area MF; metatarsal area of the foot, using the first metatarsal M1, the second metatarsal m2, the third metatarsal m3, the fourth metatarsal M4 and the fifth metatarsal M5. 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: Location map of left and right foot zones)



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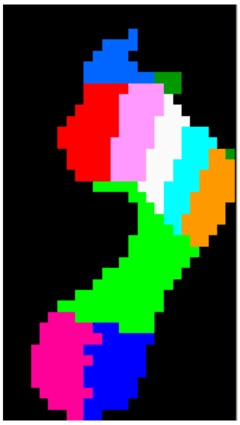

Fig.1 Left and Right Foot Zoning Map

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 2: plantar pressure zoning map) SPSS11 statistical software was used to test the single factor variance of data and analyze the significance of pressure distribution in different areas[3]. At the same time, the foot landing time, foot support period turnover characteristics were analyzed, and the differences in foot landing time, foot support period turnover between the hallux valgus group and the normal group were compared, as well as the influence of foot movement characteristics changes, forming the reference data base for shoe design improvement.

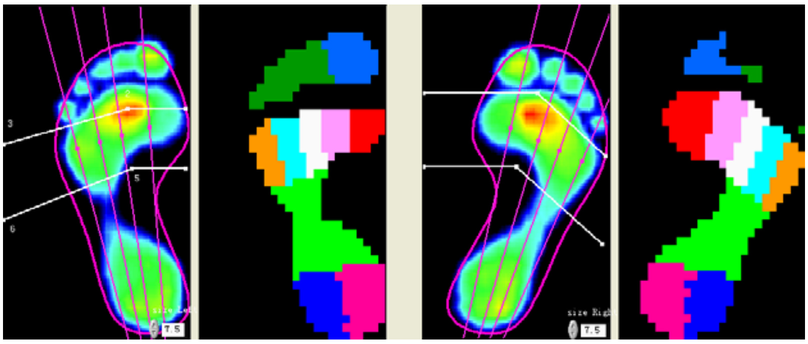

Fig.2 Plantar Pressure Zoning Map

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3. Comparison and Analysis of Research Results

3.1 Comparative Analysis of Landing Time of Foot between Hallux Valgus Group and Normal Group

First of all, the landing time of the foot in the single support stage of the human leg is compared. Generally, the landing time in the single support stage of human walking can be considered as the mark of walking speed. Through the comparison of the landing time of the foot, the difference of walking state between the hallux valgus group and the normal group can be judged, especially the impact on the landing time of the foot. In previous studies, it can be seen that the foot landing time comparison is an important parameter to judge the temporal and spatial differences of gait between the hallux valgus group and the normal group. The shortening of landing time means the acceleration of walking speed or the increase of walking frequency, which is of great significance to judge the influence of foot position changes on human gait. In this paper, we make a comparison of the whole foot landing time, and at the same time, we make a deep comparison of the three stages of the foot landing time. After the comparison of the landing time of the foot in the single support stage of the lower limbs and the heel, the whole foot and the forefoot, the difference of the landing time in the single support stage between the hallux valgus group and the normal group is shown in table 2.

Table 2 Comparison of The Feet with the Experimental Subjects(Ms)

	Hallux valgus group	Normal group	P value
Total landing time	619.1±25.2	633.2±19.8	>0.05
Heel landing time	75.5±7.8	70.2±8.0	>0.05
Full landing time	176.3±22.1	164.4±15.7	>0.05
Touchdown time	343.7±23.7	298.8±15.8	<0.01

3.1.1 Comparative Analysis of Total Landing Time between Hallux Valgus Group and Normal Group

The total landing time is the contact time between one foot and the ground, which is also called single support time. Through the comparison of the total time of landing between the experimental group and the normal group, the influence of hallux valgus on the gait kinematics parameters can be judged intuitively. The test and landing time comparison of 40 experimental subjects show that: in terms of the total time of landing, there is no significant difference between the experimental pairs of hallux valgus and the normal group, the experimental data are (619.1 ± 25.2) ms, P There was no significant difference in landing time between (633.2 ± 19.8) ms and (0.05). In the two groups, the characteristics of the total time of foot landing were the same in the single support stage. The changes of the bone structure of the metatarsophalangeal joint in the hallux valgus group did not affect the total time of foot landing. In other words, the change of the position of the metatarsophalangeal

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joint of the foot does not cause the change of the walking speed of the lower limbs.

3.1.2 Comparative Analysis of Follow-Up Time between Hallux Valgus Group and Normal Group

There was no significant difference between the two groups in the time of following the ground. The data were (75.5 ± 7.8) ms and (70.2 ± 8.0) ms, respectively. According to the structural effect of hallux valgus on the foot bone, the first metatarsal joint in the forefoot and metatarsal bone of hallux valgus patients mainly deviates outward, which has no substantial effect on the heel bone of human foot. Therefore, in the process of walking, the time characteristics of foot landing did not change substantially, and the characteristics of heel landing were consistent with those of normal subjects.

3.1.3 Comparative Analysis of the Whole Palmar Support Time between the Hallux Valgus Group and the Normal Group

By analyzing the difference of the landing time of the whole foot, we can see that there is no significant difference in the landing time of the whole foot between the hallux valgus group and the normal group. The experimental data of the two groups are (176.3 ± 22.1) ms and (164.4 ± 15.7) ms, respectively, $P > 0.05$. According to the influence of hallux valgus on the bone structure of the forepaw metatarsal of the human foot, we can see that the first metatarsal bone moves outward, The order of foot touchdown changed, which affected the time parameters, but there was no difference in the experimental results. In order to further explore the possible causes, no significant differences were found between the data of more experimental subjects. Therefore, it is reasonable to believe that hallux valgus has an impact on the structure of human forefoot metatarsal bone. The first metatarsal valgus may have a change in the landing sequence of the whole foot, while the time parameters may be affected. However, the experimental results have no impact on the time parameters Change, the result is not abnormal. The whole foot landing time starts from the moment when the heel is off the ground, and its transition process has experienced the lateral side of the arch, the fifth metatarsal, the fourth metatarsal, the third metatarsal, the second metatarsal and the first metatarsal respectively. The possible mechanism is that the compensatory effect of the bones in different parts of the foot shares the supporting effect of the first metatarsal, so that the whole foot landing time is stable and the steps are guaranteed Symmetry and normality of states.

3.1.4 Comparative Analysis of Landing Time of Forepaw between Hallux Valgus Group and Normal Group

There were significant changes in the landing time of the forefoot between the hallux valgus group and the normal group. The experimental data were (343.7 ± 23.7) ms and (298.8 ± 15.8) ms, respectively, $P < 0.01$. It can be concluded that the main reason for the difference in the landing time of the forefoot is the changes in the structure of the forefoot metatarsal bone caused by the hallux valgus between the

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experimental subjects, and the time parameters of the pressure of the hallux valgus on the sole of the foot The main influence is the change of landing characteristics of forehand [4].

3.2 Comparison of Turnover Characteristics of Foot in Propping Period

In the process of landing, the foot of normal human body is more or less characterized by varus or eversion, which is due to the rapid impact of the ground force received at the moment of landing. In order to effectively alleviate the impact of the ground, the stress of the foot and ankle occurs inside and outside overturning, on the one hand, it provides good support for the decomposition of the force, on the other hand, it turns inside and outside to a certain extent The release extends the impact time of the ground, so as to avoid excessive injury to the foot. In this paper, the characteristics of foot turnover in propping period are compared, which is the trend of excessive turnover. The trend of ankle turnover in hallux valgus and normal group was compared. By using plantar pressure test technology, the difference of distribution between inside and outside of plantar was compared. In the experimental subjects of hallux valgus and normal group, it is not only the pressure distribution characteristics of the sole that change, but also the dynamic characteristics of walking according to the theory of sports biomechanics. Therefore, by comparing the pressure distribution of the inside and outside of the foot support in different stages, we can directly observe the turning trend of the foot. In the experiment, we collected, analyzed and compared the turnover of the two groups of subjects in the following stage, the whole foot supporting stage and the forefoot pedal stage, and distinguished the two groups according to the hallux valgus group and the normal group. We discussed the difference of the internal and external forces on the sole of the two groups in the single supporting stage, the heel landing stage, the whole foot supporting stage and the forefoot pedal stage respectively, and further explained the difference in this kind of force Characteristics of ankle turnover under different forces[5]. See table 3: characteristics of foot turnover between hallux valgus and normal group for detailed comparison information.

Table 3 between Normal Group and Hallux Valgus Foot Flip Feature Table

	Normal group	Hallux valgus group
Heel landing phase	valgus	valgus
Full support stage	valgus→varus	valgus→varus
Forefoot kicking stage	varus→valgus	varus→valgus

Through the comparison of hallux valgus group and the normal group, we can see that the two groups have the same characteristics in the heel landing stage and the whole foot supporting stage. The heel landing is the trend of eversion, and the whole foot support stage is the transition trend of eversion to eversion. Combined with the situation of people's daily wear and tear of the sole, the vast majority of consumers are the first to wear the outside of the heel, that is, the foot is consciously in an inward turning feature at the moment of foot landing. Different from the test results of this study, the performance of foot eversion in this study is mainly measured under barefoot condition. The heel has lost the cushioning protection of the sole and heel, so it is characterized by eversion. The similar feature is the stage of full foot support, and the two groups of experimental subjects are all turned inside out, in which the hallux valgus experimental subjects are affected by the trajectory of the pressure center of the foot, which is consistent with the conclusion of the inversion. In the normal group, the tendency of pronation in the stage of full foot support can be understood as the normal function of the arch of foot. After the heel landing, the pressure center of the sole is respectively along: heel valgus, the fifth metatarsal of the forefoot first landing, changing to pronation, and now when the palm landing, changing to valgus. To some extent, the change of the characteristics of pronation is just one of the characteristics of the foot against and alleviating the impact of the ground Foot kinematics. Different from heel landing and full foot supporting stage, the two groups showed significant differences in the forefoot landing stage. The hallux valgus group showed significant varus in the middle stage of forefoot landing, while the normal group showed valgus. The specific turnover analysis of the feet of hallux valgus subjects and normal subjects is as follows:

3.2.1 Comparison and Analysis of Turnover Trend in Heel Support Stage between Hallux Valgus Group and Normal Group

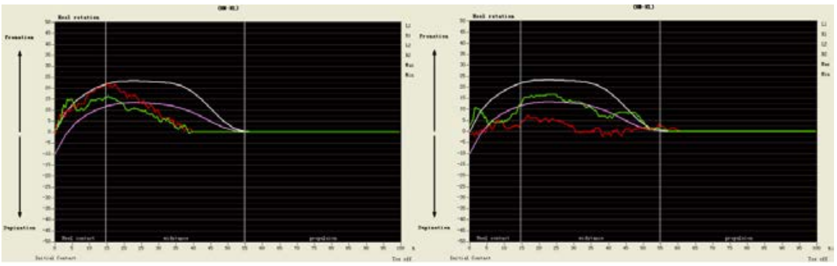

Fig.3 After the Foot Followed by a Comparison Chart

In Figure 3, the red curve shows the turning state of the right heel, and the green curve shows the turning state of the left heel. The positive direction of the vertical axis of the image shows that the force on the inside of the heel is greater than the outside, showing an eversion. The negative longitudinal direction of the image shows that the force on the outside of the heel is greater than that on the inside, showing varus.

The flipping of the heel in the single support stage is different from that in the shoe wearing stage. When the human body is barefoot, the heel landing stage shows eversion. Through the plantar pressure test at the moment of heel landing, the heel flipping of the hallux valgus group and the normal group shows eversion. Compared with fhm-fhl, the curve of fhm-fhl shows an upward trend. The inner pressure minus the outer pressure is a positive value, indicating that the inner force of walking heel is greater than the outer force. The result of hallux valgus group was consistent with that of normal group. Some researchers also designed the initial landing part of the heel of the sole as a "wing structure" to increase the support surface of the heel in the shoe state, effectively guiding and relieving the initial force of the heel landing moment. This structure design can effectively avoid the ground impact of the heel landing moment. This structure can also be used in the design of footwear products specifically for patients with hallux valgus, It relieves the impact of the foot and helps relieve the impact of the ground under the forefoot and metatarsal.

3.2.2 Comparison and Analysis of the Trend of Landing and Turning in the Whole Palmar Support Stage between the Hallux Valgus Group and the Normal Group

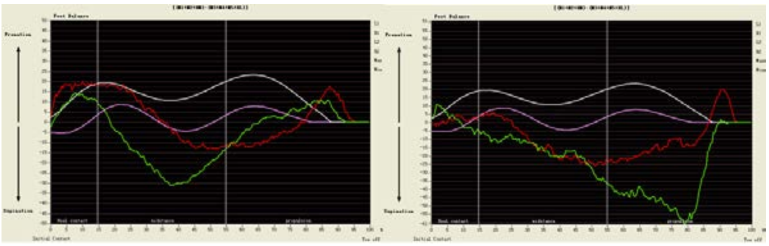

Fig.4 Full Foot Support Phase Flip Comparison Chart

In the stage of full foot support, the heel and forefoot touch the ground at the same time. In the process of foot contact with the ground, with the heel landing, the body weight is transferred to the forefoot through the heel in turn. Generally speaking, according to the fifth metatarsal sequence of the forefoot, it is gradually transferred to the first metatarsal. According to the bone sign of the foot bottom, the whole foot supporting period is divided into medial and lateral areas, and the changes of internal and external forces are compared in real time: (HM + M1 + M2 + m3) - (HL + M4 + M5), and the overall turning trend of the foot is judged. The comparison shows that: in the whole foot supporting period, the left and right feet of the hallux valgus group and the normal foot show the transition from the valgus to the valgus, and the locus of the foot pressure center is from the medial side of the foot Gradually to the outside of the foot.

3.2.3 Comparison and Analysis of the Flipping Trend of the Forefoot Support Stage between the Hallux Valgus Group and the Normal Group

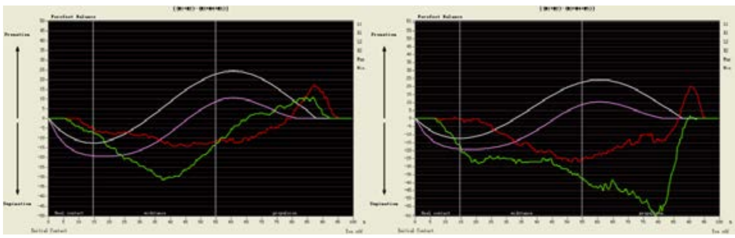

Fig.5 Forefoot Push Flip Comparison Period

Different from the following stage and the whole supporting stage of the foot, affected by the changes of the metatarsal structure of the forefoot, there was a significant difference in the turnover trend of the foot between the hallux valgus group and the normal foot during the pushing stage of the forefoot. In the landing stage of the forefoot, the turning trend of the foot gradually transits from introversion to extroversion, and the supporting part of the foot transfers from the fifth metatarsal to the medial metatarsal. Compared with the normal group, the hallux valgus group has obvious introversion in the middle of the landing stage of the forefoot, and the largest introversion occurs in 80% of the landing cycle of the foot.

4. Design Suggestion of Hallux Valgus Orthopedic Shoes

According to the experimental data, there are significant differences between the hallux valgus group and the normal group. The data are compared and the characteristics are analyzed, and the design and application of orthopedic shoes for hallux valgus patients are summarized.

First, during the design and development of hallux valgus shoes, we should fully consider the adaptive change of the insole according to the characteristics of the pressure of the sole and the action time of the forefoot, so as to improve the wearing suitability.

Second, we should fully consider the time characteristics of the human foot's sports biomechanics, and gradually correct the abnormal movement posture of the sole through the adaptive design of the sole structure based on the material and the time change of the sole pressure in the forefoot[6], so as to improve the wearing suitability of the product and achieve the best effect of correction.

Third, in the design process of the corresponding corrective shoes, we should limit the abduction of the first toe, at the same time, we should also give full consideration to restrain the outward movement trend of the first metatarsophalangeal joint, help the hallux valgus experimental object effectively control the position change of the first metatarsophalangeal joint and the first toe, and gradually correct the abnormal posture of the forefoot bone structure.

5. Conclusion

In this paper, young college students are taken as the research object. From the perspective of kinematics, through the plantar pressure test and analysis of plantar pressure characteristics of hallux valgus patients in walking state, we mainly analyzed the foot landing time, foot support period turnover characteristics and other indicators, and compared with the plantar pressure of normal people, involving kinematics, human biomechanics, materials science and footwear design science and so on Section. To study and discuss the changes of the kinematic parameters of the normal lower limbs caused by hallux valgus in young students. It will provide theoretical basis and application suggestions for the research and design of hallux

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valgus orthopedic shoes, and will also supplement the footwear category, drive the design field to carry out comfortable and functional footwear design based on human kinematics research, and promote the transformation and upgrading of the industry.

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