ANALYSIS OF VALGUS CHARACTERISTICS OF OSSEOUS STRUCTURE OF THE FEET WITH THREE-DIMENSIONAL RECONSTRUCTION TECHNIQUES

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Using the advanced MR images scan technique combined with three-dimensional reconstruction software, the study went deep into the research of feet's osseous tissue structure. After an investigation of 37 subjects' 10 indexes including valgus index and rear foot angle, the study showed distinct differences between normal foot and flatfoot. The correlation modulus of the X-ray images of flatfoot with valgus index is 0.75, and the correlation modulus with rear foot angle is 0.29. The phenomenon that most people with flatfeet had anklebone moving outside illuminated that flatfoot resulted from monstrosity of the navicular, cuneiform and metatarsus. However, rear foot angle only embodyed the relative position between calcaneus and shankbone. It couldn't explain the structure differences between flatfoot and normal foot.

KEY WORDS: flatfoot,valgus-calcaneus, rear foot angle, valgus index

INTRODUCTION: Foots' basic function is mainly to bear man's weight, cushion and absorb impulsion force. It applies thrust forward, helps adjust and maintain body's balance. The first, fourth and fifth metatarsus as well as the lowest point of the rear foot of calcaneus mainly support when a person stands statically or walks dynamically, due to his own gravity, the body's weight. Especially in movements, the feet's pressure is twice or three times more than the person's weight. It easily results that the vertical bow of the foot caves in, and that the inner lateral of navicular and astragal extrude, and that valgus calcaneus is formed, thus results in pathological changes and malformation of the feet. In the past, the study of foot was focused on externality, most of which used foot-printing method or X-ray scan to research foot's structure and functions. The study applied MRI method and three-dimensional reconstruction techniques in the research of valgus conditions of normal foot and flatfoots, aiming to carry on deep research on the causes of flatfoot, the calcaneus differences between normal and flatfoot. So we can further probe into flatfoot's structural features and means to treat and correct flatfoot.

METHODS: 37 male college students from Taipei Physical Education College voluntarily participated in the study. Each conner screened the X-ray and the MRI of the inner lateral vertical bow. We measured the angle between calcaneus's lower tangent and the first metatarsus's tangent. According to the college's initial filtering standards for flatfoot, when the angle is more than 165 degree, the foot is defined as flat. Otherwise the foot is defined as normal. So 37 subjects were divided into normal group and flatfoot group, with no obvious differences of parameters between the two groups (Table 1).
Each subject was measured in the unloaded state, with MRI technique scanning the full feet from front toe to last heel along arrow axis. We set the thickness of the image is 3mm, and stored them in medicinal image format. Every subject produced 85 images or so on average. Via the editing, modifying and storing of outline structure of every image, we got data on outlines. And then we reconstruct the modified images with three-dimensional technique.

Table 1 Physical Parameters of Subjects.

Group	Age	Height (cm)	Weight (kg)	Length of Feet (cm)	
				Left	Right
Flat (17)	21.15 ± 2.4	172.18 ± 4.3	66.75 ± 8.2	25.51 ± 0.8	24.34 ± 0.8
Normal (20)	21.75 ± 2.7	174.23 ± 7.6	68.71 ± 8.5	25.48 ± 1.3	25.43 ± 1.3

We measured the bottom plane of the feet which was formed by three points -- the lowest point of calcaneus, the lowest point of sesamoid of the first metatarsus and the lowest point of other metatarsus and got the following parameters:Angle between calcaneus and bottom plane: make a vertical plane to the bottom plane passing the central axis of the calcaneus. Measure the angle between the central axis of calcaneus and the intersect line of the two planes.Valgus index shows the relative relationship in coronal plane between ankle joint and heel. We can calculate valgus index (VI) according to the calculation formula VI = 0.5AB - AC× (100/AB) which the line between inner and outer ankles (AB), the line connecting the center of heel to the third toe (AC). C is the point where the line connecting the center of heel to the third toe intersects the line between inner and outer ankles. Plus value shows ankle joint moves inside, while minus value is outside (Figure 1). The rear foot angle means the one formed by the two straight lines between calcaneus' vertical tangent and crus's lower 1/3 vertical tangent, which can show the posture of rear foot's coronal plane and the index of movement of joint below talus, as well as when talus moved at the ankle (Figure 2).

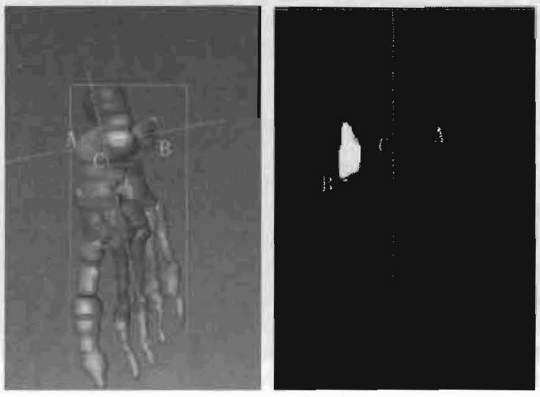

Figure 1 Valgus index.

Figure2 Rear foot angle.

We also measured the following 7 indexes related to the form of the inner vertical bow of the foot, the angle between the central axis of talus and bottom plane, the angle between the central axis of navicular and bottom plane, the angle between the central axis of cuneiform and bottom plane, the lengths of high and low bows, and the foot's length.

Analysis Methods: Calculate the average value and standard difference of all the parameters. Research the relation between left and right feet with t tests in pairs. Use Pearson relative coefficient to evaluate the relationship between the arching angle and the indexes measured on models reconstructed by three-dimensional reconstruction technique.

RESULTS: Out of 17 flatfoot subjects, there are 3 subjects whose valgus index of both feet was minus value, in addition to that, another 3 subjects whose valgus index of one foot was minus value. Except these swatches, the average valgus index of flatfoot subjects was -7.4 ± 6.0. Among 20 normal subjects, there are only 3 subjects whose valgus index of both feet is minus value, and 6 other subjects whose valgus index of one foot is minus value. Moreover, prominent difference occurred in the average valgus index of the two feet. (See Table 2).Rear foot angle reflects the posture of heel in coronal plane. 0°value means that the position of heel is veritical (normal); plus value means valgus heel; minus value means varus heel. Out of the flatfoot swatches, 2 subjects had the rear foot angle of both feet above 0°, and 8 subjects had the angle of one foot above 0°. And also in normal group, one subject had the angle of both feet above 0°and 10 subjects have the angle of one foot above 0° (Table 2).

Table 2 Comparison of indexes between normal and flatfoot group ($\overline{x} \pm s$).

Parameter	Normal	Flatfoot	P
Valgus index	7.8 ± 5.4	-7.4 ± 6.0	< 0.001
Rear foot angle (°)	-11.7 ± 5.7	-11.8 ± 5.1	> 0.05
Angle between calcaneus and bottom plane (°)	39.2 ± 3.6	34.9 ± 4.1	> 0.05
Angle between the first metatarsus and bottom plane (°)	25.38 ± 3.69	21.83 ± 2.24	< 0.001
Angle between the central axis of cuneiform and bottom plane (°)	25.30 ± 5.61	19.17 ± 6.72	< 0.001
Angle between the central axis of navicular and bottom plane (°)	21.16 ± 6.49	17.70 ± 5.92	< 0.01
Angle between the central axis of talus and bottom plane (°)	18.7 ± 4.03	19.12 ± 4.48	> 0.05
Height of high bow of the first metatarsus (cm)	5.99 ± 0.46	5.45 ± 0.4	< 0.001
Height of low bow of the first metatarsus (cm)	3.93 ± 0.51	3.12 ± 0.57	< 0.001
Length of foot (cm)	16.22 ± 1.21	16.64 ± 0.81	> 0.05

DISCUSSION: From the data and statistical proof in Table 2, we can conclude that among the 7 parameters about the form of lateral vertical bow, there are distinct differences between flatfoot and normal foot in 5 parameters, and the differences of some parameters are very prominent. Indistinct differences occur in the angle of the central axis of talus and bottom plane and the foot length. It shows that the 2 parameters have no direct relationship with the caving in of the foot. After analyzing all the 7 parameters, we found that the height of lateral vertical bow is determined by the positions of the first metatarsus, cuneiform, navicular and their relative relationship. It would cause flatfoot when their angle is abnormal and results in the shrinkage of the bow. However, their relative positions are different, which shows the causes of flatfoot are different. Some have small angle between first metatarsus and bottom plane, while their angle between cuneiform and bottom plane is rather wide. Some have small angle between cuneiform and bottom plane, while their angle between metatarsus and bottom plane is not small at all. Others are due to small angle between the axises of navicular and cuneiform and etc.

We divided subjects into flatfoot and normal groups according to X-ray results. Then we compared the results of valgus index with rear foot angle, and found that the relative coefficient of the X-ray results with valgus index is 0.75, but the one with rear foot angle is only 0.29. This illustrates that most flatfoot subjects have their ankle joint move inside. So we could judge whether it is flatfoot according to the measurement of ankle joint, or give a comprehensive judgment of the foot's symptoms after measuring several parameters simultaneously. Moreover, in the research, we also found some normal foot as well as some flatfoot judged by X-ray results have their ankle joint move inside. So we can conclude the causes of flatfoot are various. We should determine whether the foot is flat or not based on several effective parameters (such as the indexes we listed to reflect the posture of the lateral vertical bow), rather than only one parameter.

CONCLUSIONS: Analysis of the results shows that flatfoot is mainly determined by the osseous structure before talus. The changes of heel position are not a vital factor to cause flatfoot.The movement outside of ankle joint greatly influences the formation of flatfoot (the relative coefficient is 0.75). It's because of the standing parts when people stand and exercise and the incorrect supporting postures that the changes of relative position (inside and outside) chronically are caused, increasing the chance to form flatfoot. This also provided evidence to the prevention, cure and correction of flatfoot. Namely, a simple and

effective method to prevent and cure flatfoot is to have correct postures of standing and walking. Rectification of the relative position between ankle joint and heel can help remedy flatfoot. Based on the valgus index only, we cannot judge flatfoot with certainty. We need to get a deep knowledge of feet' inner osseous structure and combine multiple effective parameters which help to judge flatfoot before we confirm the symptoms.

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