Research on the Relationship of Motion State of Human Forefoot and the Changes of Heel Height

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Abstract：In this paper, the change of forefoot pressure was tested by wearing shoes of different heel height through the flat foot pressure testing system. Result shows that: the pressure of every part of forefoot in walking state from large to small was: the second metatarsal, the first metatarsal, the third metatarsal, the first toe, the fourth metatarsal, the fifth metatarsal, the second to fifth toe. From the distribution of the forefoot pressure of different parts, pressure center of forefoot moved from outside of foot to the inside with the increasing of heel height.

Key words：forefoot; heel height; foot pressure

1 Introduction

The quality of shoes and foot health is closely related to.By analyzing the difference between wearing shoes and barefoot, we can see that changing the heel height can change the mechanical state of foot with the people walking, at the same time the women's forefoot may be suffered greatly increased risk of illness,if they wear overhigh heels.For footwear products, the heel height is the main factors to influence wearer's foot stress state.In this thesis we use the footscan to measure the size of forefoot pressure in different heel height ,when the human walk., then to study what specific impact the different heel height have to the forefoot biomechanics, which provides a scientific basis for the design of high-heeled shoes.

2 Testing part

2.1 Testing Instrument

This experiment is used the Footscan Single step Mat system –USB, produced by Rsscan Company in Belgium.

2.2 Testing Objective and principle

The study selects for the nine female college students in school, of whom 22-year-old are seven, 23-year-old is one, 24-year-old is one, whose average height is 163.22cm, average weight is 50.89kg, average shoe size of testing person wearing is 37.33, of which 39 has two person, 38 has two, 37 has two, 36 has three. The fat-sized feet has one person, thin-sized feet has one, medium-sized feet have seven, the average ball girth in 20mm heel height is 223mm.Nine experimental objectives haven't a long history of wearing high-heeled shoes. When the nine students , what they wear the heel height of shoes changed from 20 to 100mm, walk flat place ,we measure motion state of different parts of forefoot . when we analyze the results, we divide forefoot into seven regions ,which are the first metatarsal, the second metatarsal , the third metatarsal, the fourth metatarsal, the fifth metatarsal, the first phalange, from second to fifth phalange, then we calculate the average of peak plantar pressure and the average of maximum pressure in three times measurements; Simultaneously at the same

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status we measure feet metatarsophalangeal ball girth with different heel height changed ,and analyze what relationship between them and the high-change has.

Tab.1 Basic information on Experimental objectives

Order number	Height(cm）	Weight(kg)	Code(France code)
1	169	60	39
2	163	49	38
3	160	45	36
4	161	49	36
5	172	52	39
6	157	53	36
7	161	48	37
8	163	52	37
9	163	50	38
Average value	163.22	50.89	37.33

2.3 Testing Method

The nine students are measured wearing different heel height shoes. When they hear of the beginning of the voice order to walk, they walk by barefoot. Their left foots step on the pressure flat firstly and begin to walk with a constant speed, up to 1.2m/s. After finishing the walk, their right foots step on the pressure flat firstly and keep the same speed to come back. After finishing a complete gait periodic motion, We can get a scatter diagram about the gait cycle of pressure on the soles of the feet. The nine students must walk more than three times on footscan and haven't any unnecessary appurtenance on their own body in order to reducing the influence of psychological factor to motion state of human forefoot.

3 Testing results

3.1 With walking in flat place, getting the change of different parts of forefoot in different heel height

According to the describing to testing method in 2.3, the nine students are measured the average of peak plantar pressure and the average of maximum pressure in three times measurements. Such as Tab. 2

Tab.2 With walking in flat place, the change of different parts of forefoot in different heel height

Part	The size of forefoot pressure in different heel height（N）									
	0	20	30	40	50	60	70	80	90	100
The first phalange	98	85.35	82.63	67.55	72.73	83.67	94.53	86.82	63.80	53.47
From the second to fifth phalange	17.8	5.60	6.93	5.20	12.37	11.90	9.40	11.43	13.27	14.80
The first metatarsal	109.91	13.96	121.73	149.20	159.83	142.53	162.33	153.91	149.56	142.67
The second metatarsal	191.51	69.25	162.33	187.80	192.00	134.60	183.10	168.50	153.24	148.50
The third metatarsal	106.91	28.05	157.90	134.40	132.67	87.07	151.43	106.90	114.30	112.54
The fourth metatarsal	74.2	70.93	72.17	61.60	58.90	63.37	62.43	60.50	58.34	57.21
The fifth metatarsal	44.5	33.40	30.20	31.10	7.90	20.30	26.23	23.41	17.35	17.12
Resultant force	642.86	06.54	633.90	636.85	636.40	543.44	689.46	611.47	569.86	546.31

According to the Tab. 2, we can know that:

(1)When the high of heel is increased from 0mm to 40mm, the pressure value of first phalange decreases continuously and the pressure value of from the second to fifth phalange decreases continuously (Figure 1);

(2)When the high of heel is increased from 40mm to 70mm, the pressure value of first phalange begins to increase and the pressure value of from the second to fifth phalange shows an increasing trend(Figure 1);

(3)When the high of heel is increased from 80 mm to 100mm, the pressure value of first phalange begins to increase and the pressure value of from the second to fifth phalange shows an increasing trend(Figure 1);

(4)with the heel height increased, the first metatarsal suffering the pressure has a change obviously. With the heel height increased from 0mm to 50mm, the first metatarsal metatarsal suffering the pressure increases continuously; When the height more than 70mm, the first metatarsal metatarsal suffering the pressure shows an decreasing trend(Figure 1);

(5)with the heel height increased, the various metatarsal always suffers a different pressure, And the second metatarsal suffers a maximum pressure.

(6)With the people walking the sort decending, Which is the pressure changing sequence to the different parts of forefoot, is as follows: the second metatarsal , the first metatarsal, the third metatarsal, the first phalange, the fourth metatarsal, the fifth metatarsal, from second to fifth phalange.

(7)The overall trend of the forefoot suffering pressure showed that: With the height less than 60mm, the pressure value of forefoot shows an increasing trend, but the trend is slow; However, with height more than 70mm, the pressure value of the forefoot is reductive with height increase (Figure 2);

(8)According to the results we know that with the heel height increasing the forefoot centre of pressure position moves to inside of foot.

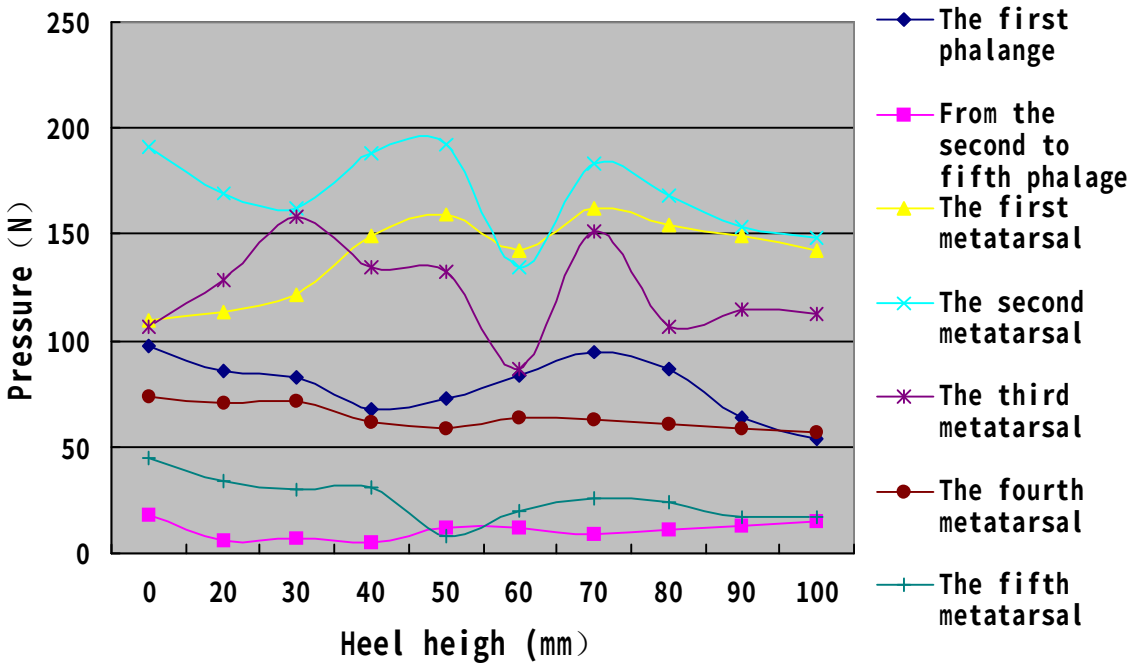

Fig 1 With walking in flat place, getting the change of different parts of forefoot after touchdown in different heel height

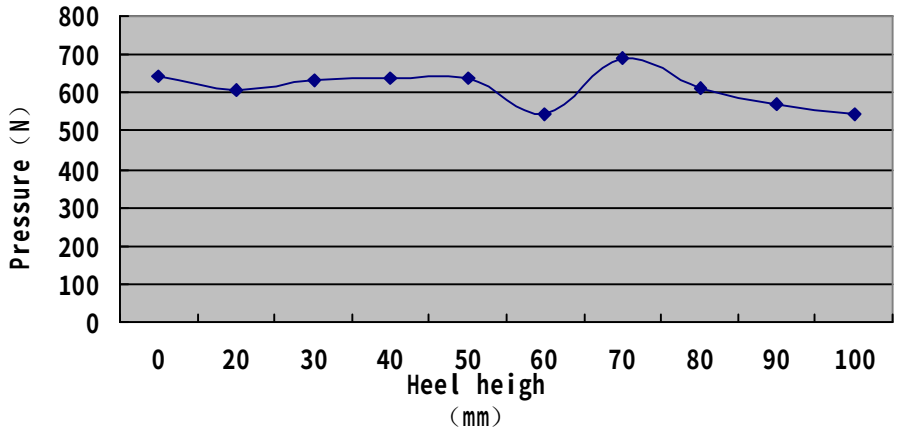

Fig 2 With walking in flat place, getting the change of forefoot in different heel height

3.2 The pressure situation about forefoot in different heel height

The figure 3 ~ 12 were three-dimensional drawings about the pressure situation of forefoot in different heel height，

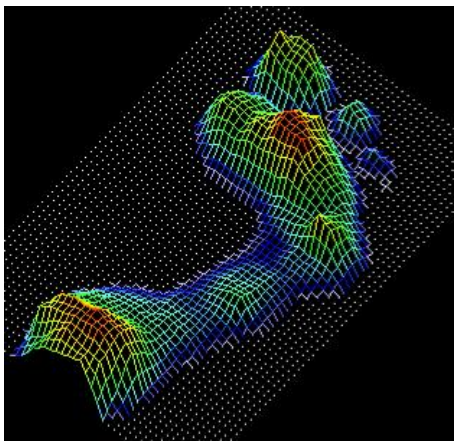

Figure 3 the pressure situation of forefoot, when the triers were barefoot,

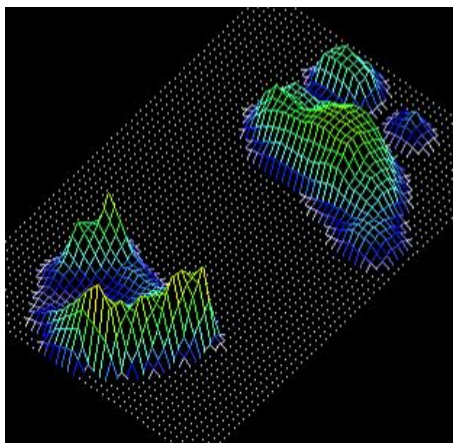

Figure 4 with the height increased to20mm the pressure situation of forefoot

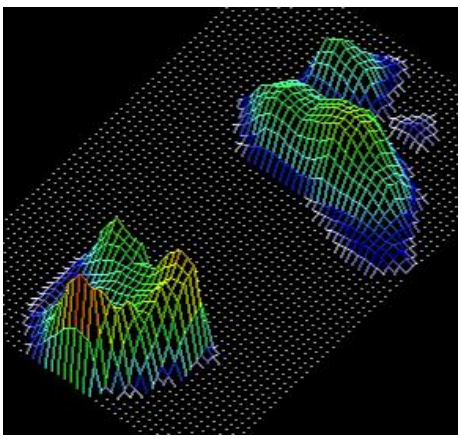

Figure 5 with the height increased to 30mm the pressure situation of forefoot

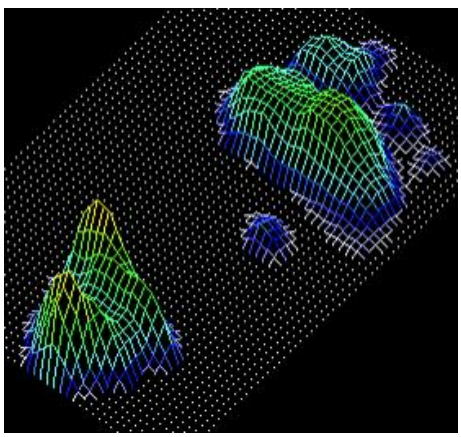

Figure 6 with the height increased to 40mm the pressure situation of forefoot

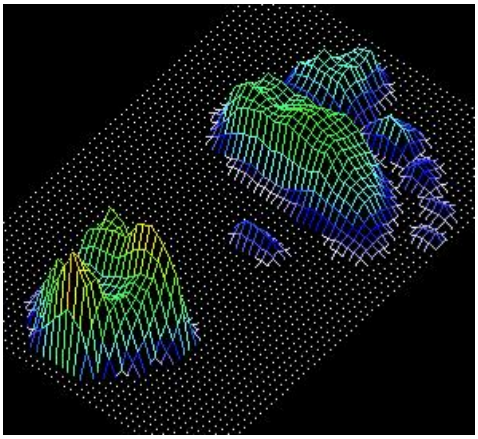

Figure 7 with the height increased to 50mm the pressure situation of forefoot

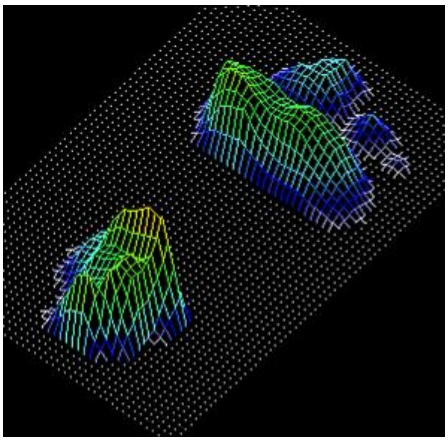

Figure 8 with the height increased to 60mm the pressure situation of forefoot

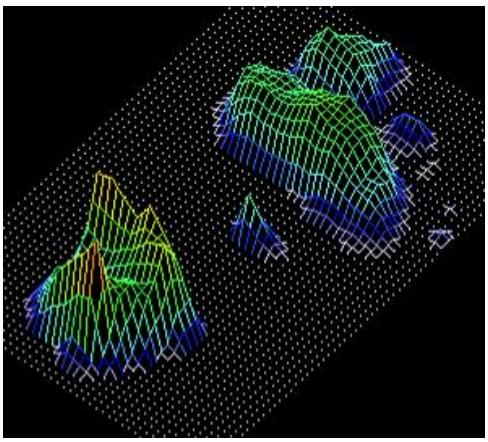

Figure 9 with the height increased to 70mm the pressure situation of forefoot

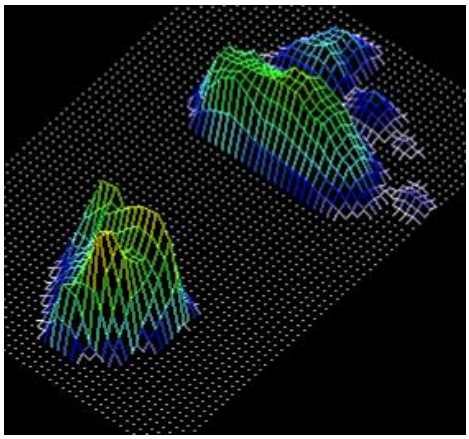

Figure 10 with the height increased to 80mm the pressure situation of forefoot

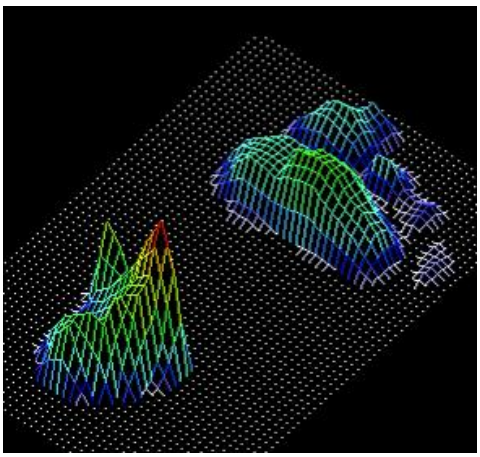

Figure 11with the height increased to 90mm the pressure situation of forefoot

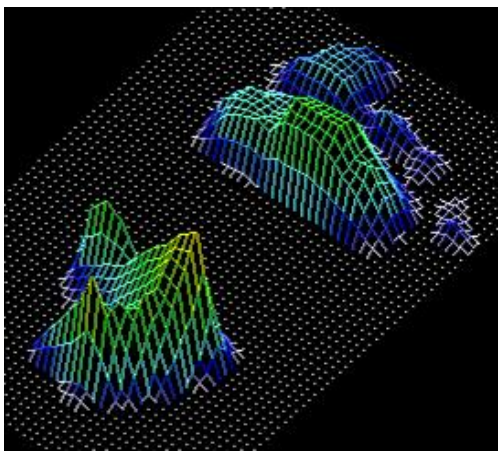

Figure 12with the height increased to 100mm the pressure situation of forefoot

According to the figure 3 ~ 12 ,we can know that: with the heel height increased, the touchdown area of metatarsophalangeal parts is reduced obviously , moreover, the touchdown area of the to fifth metatarsophalangeal is decreased most obvious,and it shows a phenomenon of peak plantar pressure clearly: At the same time, the five phalanges are

separated considerably and the total touchdown area is increased significantly. Such as Tab. 2.

with the heel height increased, the joint pressure distribution of different metatarsophalangeal parts has ultimate changes and the pressure vaule of the outside foot significantly reduces. The decrease is most obvious about pressure vaule of fifth metatarsophalangeal part and the pressure of different metatarsophalangeal parts show a phenomenon of peak plantar pressure clearly, which are distributed by a shape of bottom of the pot; At the same time , with the heel height increased, the five phalanges suffered a certain pressure. Specific values are in Table 3-5.

4 Results and discussion

After we analyzed and summarized the parts of thesis in 3.1 and 3.2, we can get overall trend of the forefoot suffering pressure. Those are: With the height less than 60mm, the pressure value of forefoot shows an increasing trend, but the trend is slow; However, with height more than 70mm, the pressure value of the forefoot is reductive with height increase. The causes of these changes are as follows:

After the triers wearing high-heel shoes, their original mode of feet are changed, what's more, the shape and pressure parts of feet are changed. As the the heel height is increased, but it is still less than 60mm, the reasons are that the leaned forward, raised the heigh of the center of gravity and leading to the front part of body. The line of gravity oversteps the stayed surface of feet. The main points bear stress of the center of gravity leans forward, correspondingly, the pressure of heel is reductive, which lead to the the pressure of half sole increased.

When high with more than 70mm, the body is more leaned forward, the center of gravity is further improved, and that is compared with the state of barefoot, the line of gravity oversteped the stays surface of feet, but The main points bear stress of the center of gravity leans backward. Since human and animal walking gait of each movement is not the legs and feet of a single sport, but it is a sport of the whole body at the unification of the nervous system under the coordination of the overall exercise, which include the implementation of the gait and posture adjustments. With the heel continuous increasing, the center of gravity is further improve, the body is more leaned forward and the balance body weakened. The body has to adjust accordingly in order to maintain body balance and body lean forward to prevent falls. The chest waist is very straight, waist lordosis increases, so that the human body can maintains the focus at the rearward position of body. It makes the pressure of the heel and part of instep are more increased than wearing the 60mm high-heel shoes, and which lead to the the pressure of half sole decreased correspondingly.

5 Conclusions

With the people walking with a constant speed, up to 1.2m/s , the sort decending, Which is the pressure changing sequence to the different parts of forefoot, is as follows: the second metatarsal , the first metatarsal, the third metatarsal, the first phalange, the fourth metatarsal, the fifth metatarsal, from second to fifth phalange. According to the results we know that with the heel height increasing the forefoot centre of pressure position moves to inside of foot.

Plantar pressure analysis is an advanced subject in the field of footwear design ,which is concerned with more and more people. Research indicates that the heel heigh become a

principal factor to change the stress situations after wearing the shoes. The author analyzed the change of motion state of human forefoot in different heel height. This conclusion is not only as a basis for designing of the women's forefoot last in different heel height and the designing to size, shape and location of convexity of tab sole of last,but also provides size and reference data of pressure for designing the shock absorption insole, midsole and special shoes, for example the design of orthopedic shoes. Simultaneously, This conclusion also provides a strong mechanical introduction for the design of high-heel shoe last.