

Study of Pregnant Women Shoes Design Based on Ergonomics

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Abstract: The features of the pregnant woman's shoes design was analyzed based on Ergonomics. Firstly, according to the group of pregnant woman foot's characteristics, three-dimensional foot-measuring instrument was used to measure the foot, the data of pregnant woman's foot were collected and analyzed, the data of foot in designing of shoes were determined. Secondly, shoes market of pregnant woman were surveyed and analyzed to contrast between China and foreign status of pregnant woman shoes, to find the problems of pregnant woman's shoe design and to bring forward improvements. Finally, the sample of pregnant woman's shoes were designed and made, the best scheme for pregnant woman was attained by the wearing tests of pregnant woman's shoes, and a set of systems for evaluating the comfort of pregnant woman's shoes was built.

Key words: Ergonomics; pregnant women's shoes; the comfort of the footwear

1 Introductions

In early pregnancy of 1-3 month, the shape of normal pregnant woman doesn't change much; in the mid-pregnancy, uterine and weight increased at the same time. The arising pressure made the abdomen of pregnant women lordosis, center of gravity back, all that make them feel hard to walk; in late pregnancy, fetal is bigger and the abdomen outstanding forward, the body center of gravity is forward. In order to maintain the balance of the body, pregnant women often take walking position of after the dump, which will make them feel pain in the back, have lower limb and feet surface edema, and have difficulty in walking. As for the feet' swelling, as well the change in shape and walking position of pregnant women, we need to improve the overall design of the pregnant women, and the main purpose of design is to change the gravity of pregnant women so as to eliminate the physical phenomenon of fatigue. The pregnant women shoes should be divided in shoes of the early stages of pregnancy (0-6 months), and shoes of late pregnancy of (7-9 months), in accordance with the phenomenon of big shape change of pregnant women in different period of pregnancy. Finally, we also need to take it into consideration that the design of pregnant women shoes should has the characters of protection of pregnant women and fetus, as well as the comfort wearing, health, convenience, etc.

2 The key points of designing pregnant women shoes

To design a pair of suitable shoes for pregnant woman, we should take the body and feet characteristics of pregnant women as the basis, and the shoes should not only have reasonable structure design and beautiful style design, but also have good health properties.

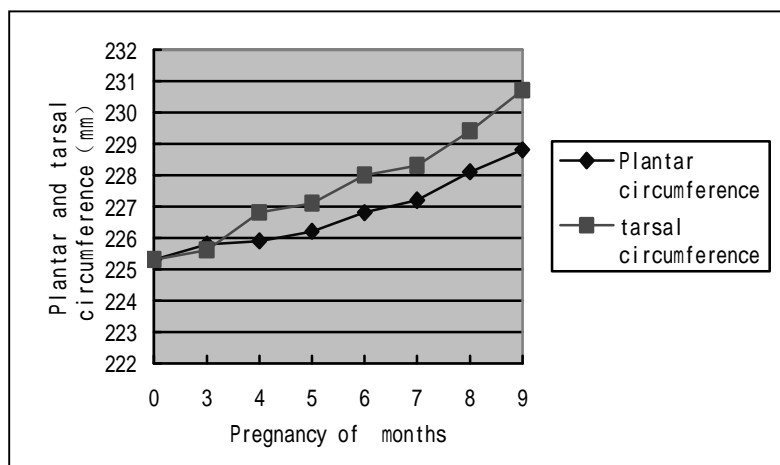
In order to solve the problem of leg edema, we measured the characteristics positions of foot; including plantar circumference and tarsal circumference to get the loose degree of pregnant women shoes. By measuring the experimental, data obtained as follows:

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Tab. 1 The plantar circumference and tarsal circumference data comparison of pregnant women (unit: mm)

Data resources	Average value of plantar circumference	Average value of tarsal circumference	Maximum value of plantar circumference	Maximum value of tarsal circumference	Minimum value of plantar circumference	Minimum value of tarsal circumference
Before pregnancy	225.3	225.3	226	227.1	223.1	224
Pregnancy of 3 months	225.8	225.6	227.1	228	224.2	224.3
Pregnancy of 4 months	225.9	226.8	227.9	228.8	224.9	225.7
Pregnancy of 5 months	226.2	227.1	228.5	229.4	225.1	226.2
Pregnancy of 6 months	226.8	228	229.1	230	225.9	227
Pregnancy of 7 months	227.2	228.3	230.5	231	226.5	227.4
Pregnancy of 8 months	228.1	229.4	230.9	231.8	227.2	228.1
Pregnancy of 9 months	228.8	230.7	231.5	232.2	227.8	228.6

We can see from Tab.1, pregnant women usually have got legs and feet swelling around 3 months of pregnancy; swollen feet will be more obvious about 6 months pregnancy, the swollen feet and legs will be outstanding on the eve of childbirth. Trough the above data analysis, we can get the curve figure of feet shape of pregnant in Fig.1.

**Fig.1 The regulation figure of pregnant women's feet shape change**

Drawn in accordance with Fig.1, the maximum plantar circumference change value of pregnant women is 3.3mm, about half type of the difference, the change value of tarsal circumference is 5.2, more

than half type of difference, the chosen of last type of pregnant women shoe should be half size bigger, such as 23 # (II) or 23 # (II half). The experimental data show that the flexibility of shoes should be bigger than 5.2mm, and is most appropriate for about 10mm in accordance with trying-use experiment.

3 The evaluation and analysis of pregnant women shoes

In accordance with the changes data of pregnant women feet, the author produced five different types of pregnant women shoes, which are suitable for pregnant women to wear. And the shoes have been wore and evaluated. The evaluation method is mainly trying-use experiment research method.

3.1 The trying-use experiment

The trying-use experiment connects the subjective sense of pregnant women with the shoes directly; the results of its evaluation can best embody the true feelings of the human body when wearing. This method is the most commonly used means of testing in present Ergonomics. It has been widely used in the comfort testing of footwear and apparel.

3.1.1 Test samples

Five different styles of end products: including sandals, in Fig.2; cotton shoes in Fig.3, single shoes in Fig. 4 and Fig.5 and home shoes, in Fig.6.

Experimental environment: 20 Celsius degrees indoor laboratory.

Subjects: The subjects were 20 healthy pregnant women of different pregnancy period, aged from 22-year-old to 28 years old, average height of 160mm, shoes yards for 36 yards, no foot disease, and the average weight of 60kg.



Fig.2 sandal



Fig.3 cotton shoes



Fig.4 Asakuchi single shoes



Fig.5 Elastic single shoes



Fig.6 home shoes

3.1.2 Experiment method

The subjects tried the five types of sample shoes on, tested and evaluated the comfort. The order is random. The subjects tried each type of the five types of the sample shoes. Test status is walking, try on pairs of shoes each time for 100 minutes.

The content of test in Table 2 and level of comfort settings have been decided through the pre-test.

3.2 The evaluation results of pregnant women shoes

In order to do better in the trying-use experiment, evaluate the trying-use results by using fuzzy comprehensive evaluation method, this article designed a comfort evaluation table in accordance with the physiological characteristics of pregnant women, as shown in table 2. Since the comfort result questionnaire is filled out by those who have been tried and tested on the target, and they do not know much about shoe-related terms, the popularization description has been used to illustrate foot shape principle in the comfort questionnaire.

Tab.2 Comfort Evaluation Table of Pregnant Women Shoes

Survey Items	Survey Feedback
a. The suitability of shoes length	<input type="checkbox"/> Too short <input type="checkbox"/> Comfort <input type="checkbox"/> Longer <input type="checkbox"/> Too long
b. Wear off convenience	<input type="checkbox"/> Comfortable <input type="checkbox"/> Uncomfortable Cause of uncomfortable:
c. The suitability of shoes width	<input type="checkbox"/> Seriously pinch <input type="checkbox"/> Pinch a little <input type="checkbox"/> Suitable <input type="checkbox"/> Too wide
d. Non-slip performance of soles and insoles	<input type="checkbox"/> Easy to slip <input type="checkbox"/> Relatively non-slip <input type="checkbox"/> Good anti-skid
e. Circumference suitability of foot joints	<input type="checkbox"/> Too big, feet in shaking shoes <input type="checkbox"/> Slightly bigger, does not affect walking <input type="checkbox"/> Suitable <input type="checkbox"/> Small, extrusion
f. The suitability of instep circumference size	<input type="checkbox"/> Too big, foot forward <input type="checkbox"/> Right size <input type="checkbox"/> The circumference <input type="checkbox"/> Too small, bound to instep
g. If the instep height can be adjusted to be applicable to the problem of pregnant women feet edema	<input type="checkbox"/> Foot gap is too large, foot upward displacement <input type="checkbox"/> Instep feels painful when walk due to oppress <input type="checkbox"/> Instep feels painful when stand due to oppress
h. If the sole hold arch	<input type="checkbox"/> Well, entirely fitting arch <input type="checkbox"/> Not to hold arch, arch empty <input type="checkbox"/> too large, against arch
i. If there is any pressure to toes	<input type="checkbox"/> No pressure <input type="checkbox"/> A little bit pressure <input type="checkbox"/> Strong pressure
j. Suitability of heel height	<input type="checkbox"/> Too short <input type="checkbox"/> Suitable <input type="checkbox"/> Too high
k. Health performance	<input type="checkbox"/> Good Sweat-absorbent and breathable performance <input type="checkbox"/> Good breathable performance but bad sweat-absorbent performance <input type="checkbox"/> Good sweat-absorbent performance and but bad breathable performance <input type="checkbox"/> Bad Sweat-absorbent and breathable performance
l. Damping effect	<input type="checkbox"/> No sense of vibration <input type="checkbox"/> Little sense of vibration <input type="checkbox"/> Larger vibration
m. Anti-fatigue of long-running	<input type="checkbox"/> Good <input type="checkbox"/> Common <input type="checkbox"/> Not good

Trying-use Result: Among the subjects, the vast majority of pregnant women feel that the design in terms of no matter shoe style, color or location of function is relative reasonable and the results are as shown in Fig.7.

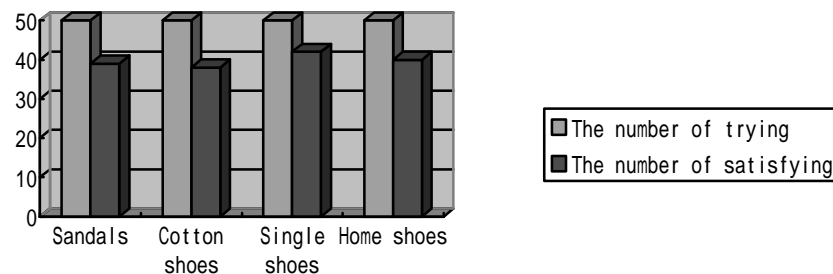


Fig.7 Satisfaction Histogram of Pregnant women shoes

In addition, the comfort evaluation forms filled by the subjects reflected the problems in the experimental shoes and revisions have been made.

4 The design principle and method of pregnant women shoes

Based on extensive market research and evaluation results of pregnant women shoes, pregnant women shoes design should follow the design features as following.

4.1 Ergonomics and last design of pregnant women shoes

Taking the feet edema problem of pregnant women into account, the best selection of Last first type is models loose, so that the toes can make a smooth open so as to help pregnant women maintain a stable center of gravity. Big round and wide head of Last types are good choices, as far as possible to avoid the use of cone-shaped type. The selection of the shoe last models should be loose-II or II half, rather than a type commonly used in half due to varying degrees of feet edema of pregnant women, so that pregnant women will not feel the instep swelling pressure.

4.2 Ergonomics and upper surface designs of pregnant women shoes

It is better to choose the easy wear-off style shoes, and the all covering shoe is a good choice. Although the style of Asakuchi shoes are very convenient to wear off, but it is not easy to hold the feet, and the pregnant women need to spend the extra effort to seize the shoes. In addition, the ankle protection function of this type is relatively weak, it is easy to get twisted feet, and may cause abortion in the early stages of pregnancy, premature delivery in late pregnancy. Therefore, it is better not to consider this model during pregnancy. Not only the elastic band and trip are convenient to wear off, but also their extension performances can ensure the flexibility of the pregnant women shoes to be around 10mm so as to solve the foot swelling problem during pregnancy, and meet different dress requirements of pregnancy.

4.3 Ergonomics and heel designs of pregnant women shoes

With the wide heel to support the body, cone-shaped with little contact with the ground area can not be used, and the design of the slope with too much contact with the ground also can not be chosen. Assembly heel style should be used, adopt root or wedge-shaped in the design, the reason is that they maybe could make arch needn't to support the body's height so to increase the stride strength, and avoid heavy weight oppression on arch to increase stability. It is suitable for pregnant women in the early stages of pregnancy wear shoes with heel height of 15 to 30mm, which can make the gravity center of the pregnant forward. While in the latter pregnancy, it was chosen to design relatively short heel, or even close to flat-bottomed design, of 10mm generally, which can make the gravity center backwards, so that pregnant women can walk smoothly.

4.4 Ergonomics and sole design of pregnant women shoes

The outsole width of pregnant women shoes is wider than the outsole width of common women's shoes, and the wear-resistant and Anti-slip sole pattern will be used. In addition, the sole weight should be light; the shoes mentioned in this article use EVA soles, which are light and non-slip.

4.5 Ergonomics and function design of pregnant women shoes

In order to solve the problem of pregnant women feet edema, the breathable layer of super-elastic fibers can be put between upper and upper lining, which will be adjusted automatically to fit the feet shape of pregnant women, so that the shoes can be wore in any period of pre-, medium-and late pregnancy. Shell fabric must be certain materials of health properties, to say the choice of leather or fabric, a layer of cotton cloth can be added in the position of instep lining and around the place, which will be not only more breathable but also more Sweat-absorbent, and this design is suitable for feet edema and daily sweat gland secretion of pregnant women, so that the feet sweat will not stay on feet, and has no occurrence of athlete's foot disease. Insoles can be doubled that the breathable non-slip insole pasted above insole with ventilation holes to the purpose of perspiration and non-slip, at the same time widening breathable insoles inside to support arch, reduce vibration and fatigue.

4.6 Ergonomics and color design of pregnant women shoes

The color use of pregnant women shoes pursuit beauty of forms while at the same time take the human body, shoes and so on practical factors into account. As for different seasons, warm green, pink, yellow and other colors can be used for spring shoes of pregnant women to create a fresh atmosphere of warm clothing, the number of color levels can be enriched. First of all summer shoes of pregnant women should give a cool, comfortable feeling to people, so high-brightness white, blue, purple, yellow and other colors should be selected, so that those who wore it appear to dress light. Winter Color of pregnant women winter shoes should not be so shallow, and the blue, green, dark and cold color with a contraction effect can be used. We can also choose a warm light tan, brown series, or color in a large area using a small color for decorative purposes, or use Decorative button and decorative pieces to the beautiful colors to match the overall feel so as to avoid being too boring.

4.7 Ergonomics and material chosen of pregnant women shoes

Taking into account the material's softness, shape and the issue of grade of women's shoes, natural leather with relatively good health properties is the first materials should be chosen for pregnant women. Soft high quality leather and goatskin are good choices for the mid-range shoes of pregnant women, and high-quality calfskin is the first choice for high-grade shoes of pregnant women.

The first layer pig skin with breathable performance and an affordable price will be used for lining of mid-range shoes of pregnant women, while the goat skin lining will be used to design the top-grade shoes of pregnant women.

Polyurethane or TPR with light weight and anti-skid features can be chosen for sole. A certain soft EVA material can be used for the purpose of reducing weight, decompression and damping, combined with the most suitable large solid 20 mm high heels, and so to effectively prevent post-natal spine pain.

5 Conclusions

In accordance with the design and comfort evaluation results, we summarized design principles and methods of pregnant women shoes as follows:

Pregnant women shoes design principle must be people-oriented, and carry out the design strictly by taking to the human characteristics of pregnant women as the basis, so as to protect pregnant women and intra-abdominal fetal health, as well as pay attention to the tremendous changes of psychological feelings

and maternal size. Pregnant women shoes design is to make women feel comfortable wearing, and to minimize the mental irritability and fatigue of the physiological phenomenon.

Pregnant women shoe design should be fashionable and generous; Shell fabric and instep lining should be moisture absorption, air permeability; sole materials be considered moderate severity, wearable, non-slip, and a good shock absorption performance, additional burden should not be given to pregnant women; heel height should be moderate, it is not suitable for pregnant women to wear high heel shoes, it is necessary to take the phenomenon of different gravity center of the pre-and post-pregnancy into consideration, to adjust the gravity center by the height of the heel so as to reduce the fatigue of pregnant women; heel type is generally large rooted design, and it is smooth and comfortable; help the design of outsole structure or materials must be convenient to wear-off..

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