FINITE ELEMENT MODEL CONSTRUCTION AND DESIGN OF PRESSURE-REDUCING PHYSIOTHERAPY SOCKS FOR DIABETIC FOOT

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Abstract. The development of diabetic foot ulcers (DFU) is associated with abnormal concentration and distribution of foot pressure and shear stress during walking or standing in the human body. It has been demonstrated that Ecoflex gel can disperse and reduce foot pressure to different degrees for diabetic foot ulcer (DFU) disease. This paper will provide an overview of the diabetic foot pathology characteristics, semi-wrapped pressure-reducing insole design and effectiveness experiments, as well as a model to derive the appropriate material elasticity. The effect of Ecoflex gel material physiotherapy socks on plantar force distribution will then be

investigated by using data from plantar pressure tests and peak stresses at the study site to verify its effectiveness.

Study on decompression appliance for diabetes foot. In the 1880s, the British Beely officially opened the research on plantar pressure measurement technology **Ошибка! Источник ссылки не найден.**, which was limited by the technical background at that time and did not obtain a complete foot pressure distribution. Research related to plantar pressure distribution has been widely used in various military as well as civilian fields, and then related research has been carried out in various countries around the world, and test methods for plantar pressure such as footprint method, topography method, optical measurement method, force measuring pad/table and pressure shoes/insoles have appeared one after another[2][3][6].

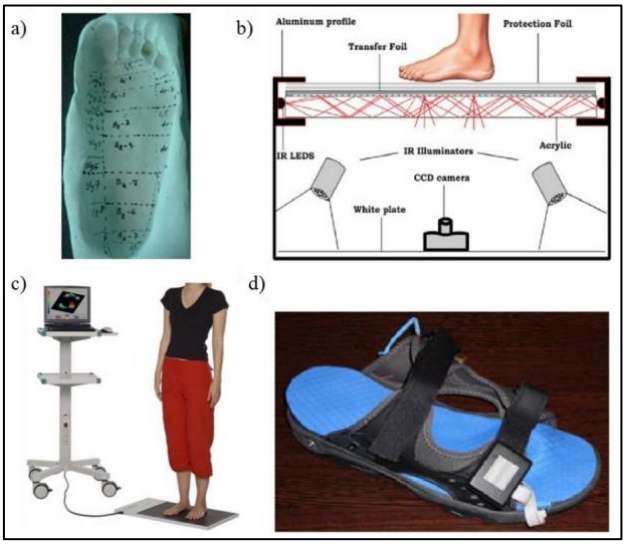

Figure 4. Plantar pressure measurement method

a) Footprint method**Ошибка! Источник ссылки не найден.**; b) Optical measurement system [2]; c) Force plate [3]; d) Plantar pressure measurement shoe[6]

Lemmon et al**Ошибка! Источник ссылки не найден.**used experimental and quasi-

static plane strain finite element methods to investigate the variation of sub-metatarsal head pressure in the second metatarsal head about insole thickness and tissue thickness and showed that the peak pressure decreased with increasing insole thickness. As the insole thickness increases, the increment of peak pressure decreases and the pressure seems to converge to an asymptote, i.e., more cushioning material has almost no pressure-reducing effect. The smaller the tissue thickness of the footbed, the greater the pressure drop as the insole thickness increases.

In comparing plantar pressure parameters between elderly diabetic patients and normal elderly people Deng Junmin et al [7] found that there were significant differences between the two groups of healthy and diabetic patients in terms of eight indicators such as the loading rate of metatarsal zone 3 of the right and left foot and peak pressure, support time in the T2 ~ T5 region of the left foot, impulse in the M3 region of the right foot, impulse in the M1 region of the left foot, and impulse in the M3 region of the left foot. It was concluded that the greater force on the mother toe and forefoot during walking, inadequate cushioning, and long support time are important reasons why diabetic patients are prone to ulcers in this area **Ошибка! Источник ссылки не найден.**.

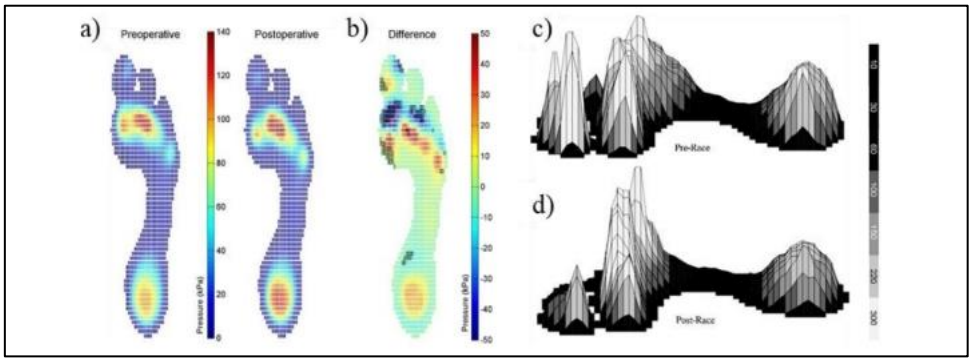

Figure 5. Plantar pressure cloud map

Conclusion of foot pressure testing and modeling. The initial stage of the gait process is the single-footed landing period, see Fig. a), which is about 5% of the gait cycle, when only the heel position is in contact with the support surface, so there is pressure distribution only in the heel position in the plantar pressure distribution cloud, while the arch and forefoot are suspended; b) is the full-footed landing period, which is about 30% of the gait cycle simulated in the experiment, when the left foot is fully landed and the right foot is in the heel lift period. The center of gravity is still in the posterior orientation, so its pressure distribution cloud is similar to that of standing; finally, at about 50% of the gait cycle, the left foot heel is raised and the right foot is fully on the ground, at which time the center of gravity shifts forward and the body swings forward, and the left foot plantar pressure state is presented as shown in Figure c).

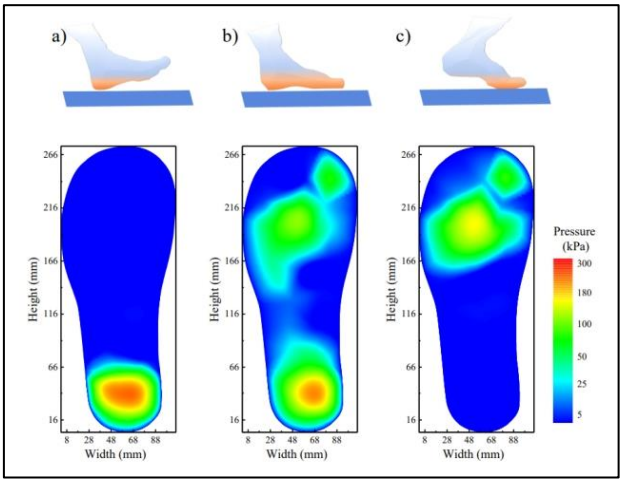

Figure 6. Gait cycle variation

Contours of the deformed finite element foot are shown below each stick figure with close-up von Mises stress distributions for the heel on the ground,

middle stance, and toes off the ground (from left to right)[8]. The intermediate stance stress contours show how the "strain" solution modifies tissue loading during the minimization of maximum strain energy density. Material responses of soft tissues and anatomical details of foot structure are highly relevant to the study of loading and contact conditions that may contribute to diabetic foot ulcers**Ошибка! Источник ссылки не найден.**. The loads and pressures typically measured in the gait laboratory may not always reflect the extent of underlying tissue deformation. Initial findings and their clinical implications will be further explored following future model validation**Ошибка! Источник ссылки не найден.**.

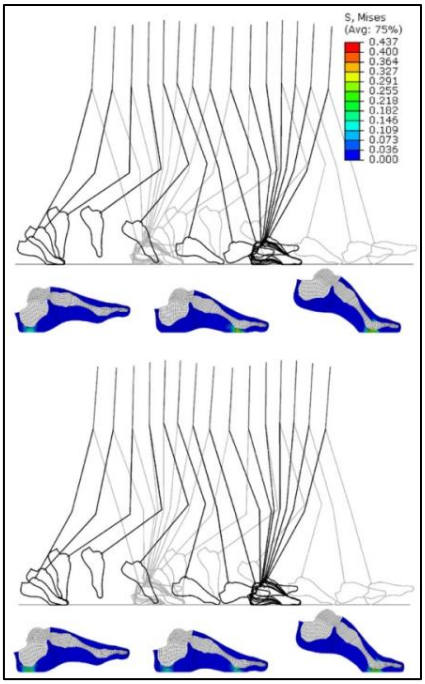

Figure 7. Measurement results of the gait cycle

There are two general tests in China, the first one is to compare with the test in real-life situations, and the second one is to compare the results with similar models built by high-level literature. Yang Yunfeng et al [11] tested the

stress and displacement of the foot bones by building a three-dimensional finite element model with pressure loading and also performed mechanical loading tests with seven fresh cadaver foot specimens to measure the displacement and pressure of the normal foot, with which the comparison showed the same performance in terms of trend changes, but with some differences in values, making it difficult to simulate the correlation between normal materials. Tao, K. et al[12] compared the predicted map of plantar pressure contact distribution of the model with that of the testers' F-scan. He [13] et al. compared the obtained results with those of KIDO HO KOTWIEK et al. and confirmed the match. Liu Lifeng et al [14] compared with the study of Jacob et al and the error was within 1 MPa.

Plantar pressure distribution measurement is to obtain the pressure relationship between the plantar surface of the foot and its support surface in any postural state of a person. The human foot is mainly composed of the foot bones, muscles, ligaments, and joints, and the foot bones contain a total of 26 bones, more than a quarter of the total number of bones in the human body **Ошибка! Источник ссылки не найден.**, and the plantar pressure distribution is influenced by the biomechanical structure of the foot.

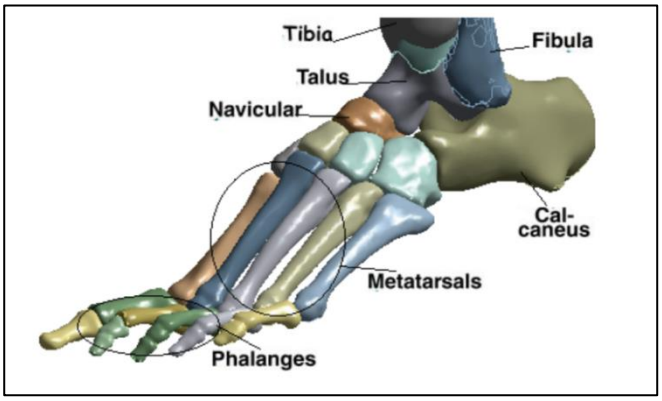

Figure 8. Skeletal structure of the foot **Ошибка! Источник ссылки не найден.**

The accuracy of the computational results of the finite element model is mainly influenced by the definition of material parameters and loading conditions, and in the human Within the field of biomechanics, the biggest problem encountered in finite element analysis is the uncertainty of material properties**Ошибка! Источник ссылки не найден.**[8], and the correctness of the model itself and its simulation results is extremely important, which requires us to validate the validity of the established model to ensure that the model results usually provide a direct basis for clinical applications**Ошибка! Источник ссылки не найден.Ошибка! Источник ссылки не найден.**.

Summary. This project focuses on the current social situation that the prevalence of diabetic foot continues to increase, and takes type 2 diabetic patients as the core user of the study. Through user research on diabetic patients and diabetic doctors, we extracted the needs of users and summarized them, to propose the main points of product design based on user needs. The final design object is a pressure-reducing physiotherapy sock suitable for type 2 diabetic foot patients. Through this product, we aim to reduce and disperse the pressure on the feet of type 2 diabetic patients and delay the development of sugar foot.

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