RESEARCH ON DECOMPRESSION OF HIGH PRESSURE VALUE IN TYPE 2 DIABETIC FOOT BASED ON MULTIDIMENSIONAL EVALUATION ANALYSIS

Wang Jianping, Donghua University, Master's degree first year
Li Huifang, Donghua University, Second year of Master's degree
Chen Jinze, Donghua University, Second year of undergraduate
Yuan Ding, Donghua University, First year of undergraduate
Advisor:Tang Feifei, Lecturer,Position Director of Student Affairs Office, School of Computer Science and Technology
Donghua University
Shanghai, China

Review. Neuropathy around the feet, loss of sensation in the extremities, and abnormally high plantar pressure allow patients to traumatize the foot without awareness, while the wound becomes infected and spreads under their foot, eventually leading to amputation.

The foot is the weight-bearing interface between the ground and the body. It is subjected to high stresses and strains during walking, especially in the heel area during heel strike, and in the forefoot area during toe-off. Long-term exposure to high repetitive stress and shear on the sole of the foot will lead to destruction of plantar tissue . Plantar soft tissues, such as the heel fat pad and plantar head pad, are specialized structures whose viscoelasticity allows them to deform to facilitate shock absorption during walking. As a result, damaged soft tissues may not be able to transfer weight during walking, which could eventually lead to amputation of the foot.

Additionally, diabetics are prone to ulcers due to risk factors such as neuropathy, lack of sensation, muscle wasting, or foot deformities. For example, glycosylation of collagen and stiffer plantar tissues leads to a reduced fitness of the tissue to repetitive stress, leading to a higher incidence of ulceration. In addition, foot deformities such as hammer toes or Charcot feet may lead to elevated plantar pressure, which has been reported to be a contributing factor to diabetic foot ulcers in the region of the first metatarsal head and hallux. Foot ulcers in diabetics often become infected because their feet are insensitive, which can lead to serious lower limb amputations.

Pressure Point Analysis of Foot Contact Surface Based on Gait Cycle. The human foot has the functions of support, weight bearing and cushioning, enabling humans to perform actions such as walking, running and jumping. Gait refers to the posture of a person during walking, including the swing amplitude and angle of the lower limbs. Gait can be divided into unconscious and conscious gait processes. The unconscious gait process is a gait process that is naturally formed

in daily life. In this process, the person's step length, step width, and step frequency are stable and the formed plantar pressure can be used as data for biometric identification. source. In addition, the conscious gait process refers to the plantar pressure distribution formed by the individual's voluntary control when the plantar pressure is abnormal. For example, the diabetic foot caused by the complications of diabetic patients will have plantar ulceration, and the position of the ulceration is often in the area with the highest pressure. Therefore, pain is felt during static standing or walking, thereby forming a conscious plantar pressure distribution. Through the analysis of the plantar pressure during the gait process, specific data can be provided for medical diagnosis; in addition, the collection of the plantar pressure distribution signal during the gait process can provide optimized parameters for sports, industrial design, and robot control.

The measurement of plantar pressure distribution is to obtain the pressure relationship between the sole of the foot and its supporting surface in any posture state. The human foot is mainly composed of foot bones, muscles, ligaments and joints. The foot bones contain a total of 26 bones, more than a quarter of the total number of human bones. The distribution of plantar pressure is affected by the biomechanical structure of the foot.

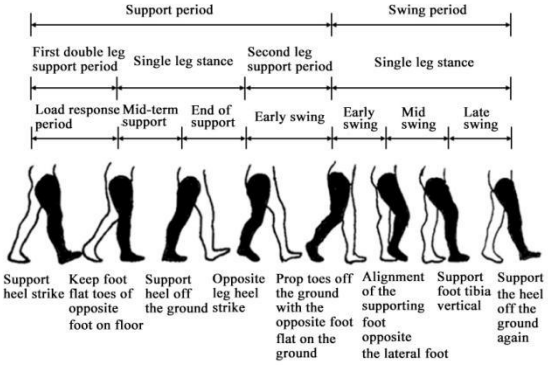

Figure 1 The stance phase and swing phase in the gait cycle

The normal gait process is divided into two processes, the support phase and the swing phase. As shown in the figure, the support phase accounts for 60% of the total time, and the swing phase accounts for 40%. For normal people, the left and right feet are symmetrical Gait process, and the distribution of plantar pressure is also symmetrical, so it can be characterized by the distraction of single-foot pressure distribution during the analysis process.

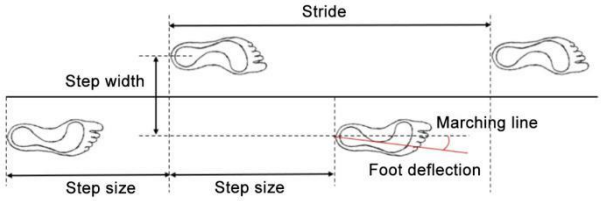

Figure 2 Schematic diagram of gait distance

It can be seen from the above figure that at the beginning of the gait, the heel of the right foot touches the ground, which accounts for about 0-15% of the gait cycle. In the second stage, the support phase of the right foot enters the middle stage and is 15%-40% of the gait cycle. When only the forefoot is on the ground, it is at about 40%-50% of the gait cycle. When only the phalanx of the right foot touches the ground, it is the end of the right foot support phase, which is about 50%-60% of the gait cycle. It is the entire time phase range of the left foot support phase.

The contours of the deformable FE foot are shown below each stick diagram, with close-up von Mises stress distributions for heel strike, middle stance, and toe lift (from left to right). The intermediate stance stress profile shows how the "strain" solution modifies tissue loading during the minimization of the maximum strain energy density. The material response of the soft tissues and anatomical details of the foot structure are highly relevant for the study of loading and contact conditions that may lead to diabetic foot ulcers. Loads and stresses commonly measured in gait laboratories may not necessarily reflect the extent of underlying tissue deformation. The initial findings and their clinical implications will be further explored after future model validation.

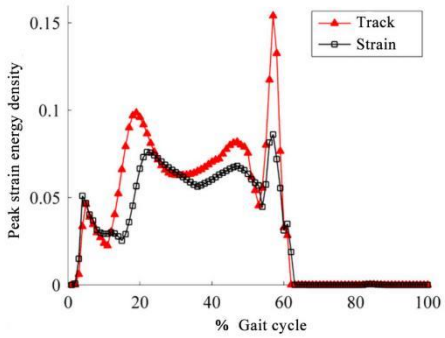

Figure 3 Legend of peak strain energy density as a function of percentage of gait cycle

Peak strain energy density as a function of percentage of gait cycle. 0% means heel strike, while toe off occurs approximately 60% of the cycle. The physical location of peak strain energy density occurs at progressive locations of plantar tissue throughout the cycle, from heel to toe. The maxima within the cycle occur in the plantar tissue just before the toes and just below the metatarsal heads.

The plantar pressure was monitored by multi-body system modeling table, surface electromyographic signal (SEMS), Semmes-Weinstcin 10 g monofilament detection method, etc.. Use plantar pressure monitoring technology and devices to find common pressure points in diabetic foot patients. Plantar pressure detection is an important aspect of physiological monitoring, and plantar pressure monitoring technology is also widely used in the design of various

medical footwear and experimental test footwear. The structure of the wearable foot test system consists of three parts: pressure sensor, data acquisition device, and signal display terminal.

Because each person's walking posture is different, it has a certain impact on the tested plantar pressure and gait stability curve. Therefore, patients should be trained in gait before the test to ensure the objective and valid test data. And the patient wears loose soft shoes every day, and the pedometer calculates the daily activity volume, and maintains the daily activity volume of 3000-5000 steps. The patients were asked to take off their shoes and wear socks, and walk 3 m on the test platform with normal gait after standard walking training. The patient's plantar pressure was measured by the measuring instrument, and the supporting software Footscan Software 7.0 was used for data collection and analysis, and the test was repeated 3 times, and the most stable walking gait was selected to analyze the plantar pressure distribution. In this study, the foot was divided into 10 anatomical divisions, namely, the first toe (T1), the second to fifth toe (T2 to T5), and the first, second, third, fourth, and fifth metatarsals were M1 and M2, respectively. , M3, M4 and M5, mid-plantar (MF), medial heel (HL) and lateral (HM). Red areas on the manometer image indicate abnormal plantar pressure, and blue areas indicate normal pressure. Stockes et al. have pointed out in the report that compared with the general population, patients with diabetic foot ulcers not only have an increase in plantar peak pressure, but also found that the population has a tendency to transfer plantar pressure to the lateral part. Therefore, relevant scholars believe that in the case of normal walking in diabetic patients, the continuous high pressure on the soles of the feet is the cause of plantar ulcers. Therefore, balancing plantar pressure is an important way to prevent plantar ulcers, and it is also one of the design principles of diabetic shoes.

The experiment will be divided into two groups, namely the treatment group and the control group. The treatment group wore gel decompression insoles, and the control group wore ordinary insoles. Surface Electromyogram Signal (SEMG) is an electrical change that accompanies the central nervous system to control muscle activity, and is an important method for non-invasive detection of muscle activity on the body surface. SEMG has the characteristics of weakness, alternation, and low frequency. Using SEMG sensors can process the measured signals in a series. The solid line in Figure 1 is the SEMG of the vastus lateralis muscle collected by the sensor, and its sampling frequency is 250 Hz . Because the system has its own function of removing zero drift, there will still be a certain zero drift voltage in the actual single-chip microcomputer acquisition. The non-stationary characteristics of the signal make the characteristic parameters needed

to judge the starting moment of the muscle action change with time, so it is impossible to obtain the starting moment of the movement strictly in real time. In some studies, the wavelet analysis method is usually used to analyze the non-stationary signal. Denoising processing, when the heel touches the ground, its output is high level, otherwise it is low level, and its rising edge is the moment of heel touchdown, and the most recent action starting moment before this moment (myoelectric signal trough position) is tup.

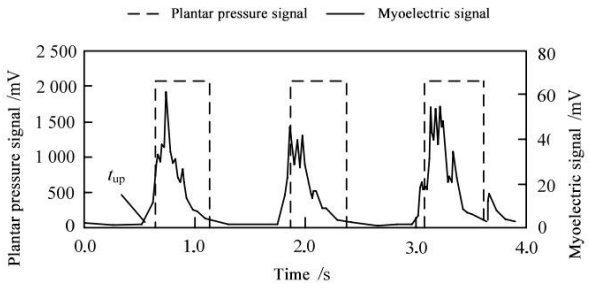

Figure 4 Comparison of EMG signal and plantar pressure signal

The Belgian Footscan plantar pressure gait analyzer was used to monitor the dynamic plantar pressure before and after wearing insoles in the two groups of patients, and the changes of plantar blood flow were detected by B-ultrasound. Semmes—Weinstcin 10 g monofilament detection method is used to detect sensory changes, and ten parts of the plantar are selected for sensory measurement, including the 1st to 5th toes, the 1st, 2nd, 3rd, 5th metatarsal heads and the heel. If there are 2 points and The above paresthesias are considered as protective sensory loss. In addition, both groups of patients were given a comprehensive treatment plan for diabetes. The goal of blood sugar control: refer to the blood sugar control goals of the vast majority of patients hospitalized in the non-emergency department of the Endocrine Society (ENDO), that is, the fasting blood sugar is below 7.8mmol/L, and the 2-hour postprandial blood sugar is 10 mmol/L or less.

The Wagner grading method for diabetic foot is currently the most classic grading method, which is widely accepted and used clinically. This grading classifies diabetic foot into 0-5 grades according to the severity of the patient's condition, as shown in the figure.

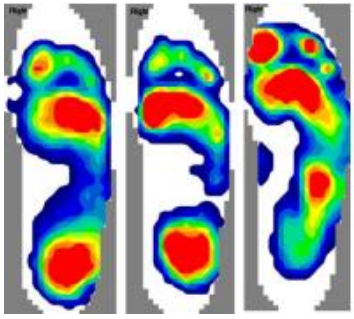

Figure 5 Dynamic plantar images of different groups

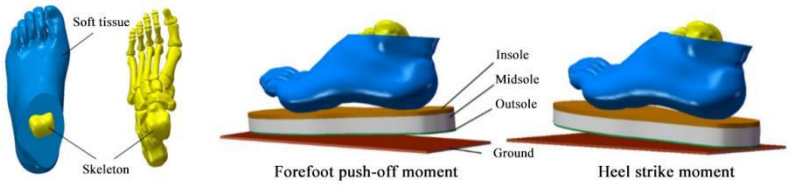

Figure 6 Wagner classification of diabetes

The pressure on the toes varies among different foot carriers. Use visual analog scale (VAS): use a 100mm horizontal straight line, and set the two ends from no pain to the most painful. The subject quantifies the pain intensity by drawing a vertical line at the place closest to his own pain level. VAS has been proven to be an effective and reliable method for evaluating acute and chronic pain in elderly patients.

Grading	Clinical manifestations
Level 0	Have risk factors for foot ulcers, currently no ulcers
Level 1	Superficial ulceration, clinically non-infected
Level 2	Deeper ulcers, often with soft tissue inflammation without abscess or bone infection
Level 3	Deep infection with bony tissue lesion or abscess
Level 4	Localized gangrene (toe, heel, or fore dorsum)

Figure 7 Pain Evaluation Scale

This study focuses on the current social situation where the prevalence of diabetic foot continues to increase, takes type 2 diabetic patients as the core users of the study, and explores how to slow down the further development of diabetic foot by reducing plantar high pressure and decompression. Compared with foreign research on diabetic feet, most of the relief devices for diabetic feet in China still rely on the data models of foreigners' feet. Urgent demand, the country needs to formulate a good specification and industry standard recognized by the domestic market and users.

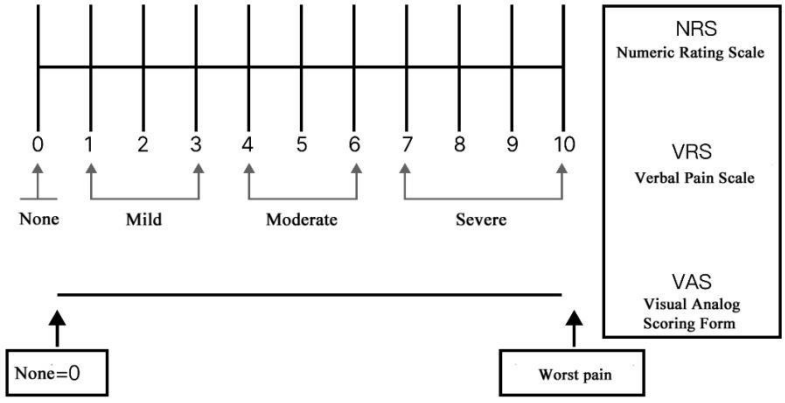

Figure 8 Pain Evaluation Scale

Summary. Through the analysis of the pressure point of the foot

contact surface based on the gait cycle, the multi-body system modeling table, the surface electromyographic signal (SEMS), the Semmes-Weinstcin 10 g monofilament detection method, etc., the plantar pressure monitoring and the subjective measurement of the diabetic foot were studied. Through table analysis, we can clearly know the state of diabetic foot patients in different surrounding environments, so as to provide data guarantee for the treatment aimed at reducing plantar high pressure and delaying the development of diabetic foot.

References

[1] James, S.K., Lindahl, B., Timmer, J.R., et al. Usefulness of biomarkers for predicting long-term mortality in patients with diabetes mellitus and non-ST-elevation acute coronary syndromes (a GUSTO IV substudy). Am J Cardiol, 97, 2 (Jan. 2006), 167-172.

[2] Halloran, J.P., Ackermann, M., Erdemir, A., & van den Bogert, A. J. Concurrent musculoskeletal dynamics and finite element analysis predicts altered gait patterns to reduce foot tissue loading. Journal of Biomechanics, 43 , 14 (2010), 2810-2815.

[3] Jacob, S., Patil, M.K. Stress analysis in three-dimensional foot models of normal and diabetic neuropathy. Frontiers of Medical and Biological Engineering, 9, 3 (1999), 211-227.

[4] Chao, Y.Z. Biomechanical properties of the forefoot plantar soft tissue as measured by an optical coherence tomography-based air-jet indentation system and tissue ultrasound palpation system. Clinical Biomechanics , 25 (2010), 594-600.

[5] Özkan A, Atmaca H, Mutlu İ, et al. Stress Distribution Comparisons of Foot Bones in Patient with Tibia Vara: A Finite Element Study[J]. Acta of Bioengineering Biomechanics, 2013, 15(4): 67-76.

[6] UMPIERREZ G E，HELLMAN R，KORYTKOWSKIM T．et a1．Management of hyperglycemia in hospitalized patients in non—critical care setting：an endocrinesociety clinical practice guideline[J]．J Clin Endocrinol Metab，2012，97(1)：16—38．

[7] Crisan S, Zaharia V, Curta C, et al. Computer Assisted Optical Podoscope for Orthostatic Measurements[C]. International Conference on Advancements of Medicine and Health Care through Technology. Springer. 2011: 226-229.

[8] D'Addio G, Iuppariello L, Pagano G, et al. New Posturographic Assessment by Means of Novel E-Textile and Wireless Socks Device[C]. 2016 IEEE International Symposium on Medical Measurements and Applications (MeMeA). IEEE. 2016: 1-5.

[9] Diabetes mellitus, fasting blood glucose concentration, and risk of vascular disease: a collaborative meta-analysis of 102 prospective studies. Emerging Risk Factors Collaboration.Sarwar N, Gao P,

Seshasai SR, Gobin R, Kaptoge S, Di Angelantonio et al. Lancet. 2010; 26;375:2215-2222.