FINITE ELEMENT MODELING AND KINESIO TAPE DESIGN BASED ON ILIOTIBIAL BAND SYNDROME

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Introduction : With the development of national fitness public services, running, as a simple and effective way of exercise, has become a sport with high participation of the masses. But because of the lack of scientific guidance, sports injuries have become more common, with the iliotibial band being the most complex. Although there have been many clinical studies on iliotibial band syndrome, there are relatively few studies on biomechanical modeling related to it. Due to the complex coupling relationship between tissues at the lower extremity where the iliotibial band is located, and the problem of unsteady mechanical properties in multi-tissue motion cycle, it is difficult for traditional mechanical analysis methods to quantify the internal force and deformation of tissues. Therefore, it is of great significance for subsequent design of corresponding products to conduct biomechanical research on iliotibial band by using finite element modeling and analysis method and establish lower limb biomechanical model to study the load distribution of iliotibial band.

Intramuscular patch is used to treat joint and muscle pain, and has been widely used in sports medicine and injury prevention fields [1]. However, the intramuscular effect stickers on the market are all long strips, which need to be trimmed by oneself. At the same time, there is no standard and feasible teaching method for binding stickers, which makes users unable to specify the location of binding stickers, resulting in non-standard binding stickers.

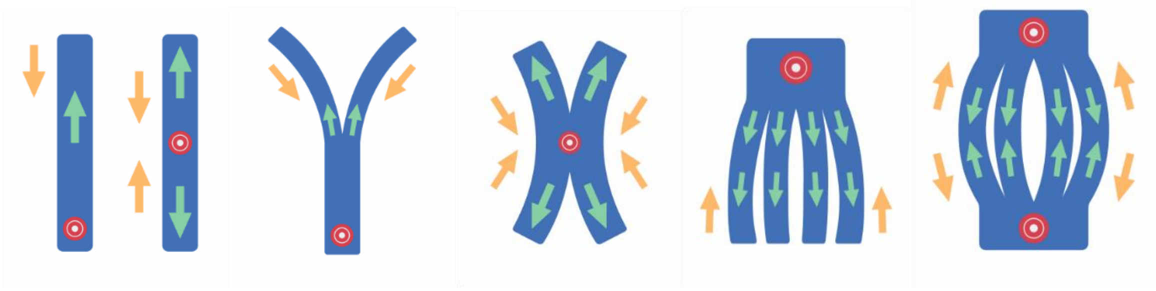
By establishing a human body model, finite element analysis simulates the force and deformation of human body tissues by means of surface loading, quantifies the internal change information of human body, and provides technical means and theoretical basis for clinical musculoskeletal biomechanics research. Predecessors have explored foot diseases, knee injuries, occupant pedestrian collision injury simulation and other aspects, but mainly for bone analysis, soft tissue research is not rich.

Therefore, this study will study the design of intramusicular effect patch for the adjuvant therapy of iliotibial band syndrome, construct the lower limb model auxiliary design based on finite element modeling, conduct subjective and objective experiments on the effectiveness of the product, and evaluate the effect through electromyographic signal, which is of great significance for preventing and alleviating the occurrence of iliotibial band syndrome and improving muscle function.

Research status : Iliotibial band syndrome is one of the many causes of lateral knee pain. It is a disease with lateral knee pain as the main symptom caused by fatigue or tension of the iliotibial band and repeated friction with the femoral condyle [2]. The iliotibial tract is a longitudinal strip of aponeurosis formed by the thickening of the fascia lata on the outer part of the thigh. It is the tendon that connects the tensor fascia lata to the gluteus maximus [3]. This structure is particularly susceptible to changes in the mechanics of running.

At present, lower extremity finite element model is mainly used to predict lower extremity injury caused by road collision between pedestrian and occupant. Beillas et al. [4] established a lower limb finite element model, which included anatomical features from the foot to the buttocks. Kim et al. [5] improved the lower limb model established by Beillas et al., and combined the model with existing models of other human body parts to build a complete human body model. In addition, the lower extremity finite element model is also applied to the design and optimization of pressure fabrics. Ghorbani et al. [6] endowed the human leg model with material properties with biomechanical properties and constructed a finite element model of human leg-elastic weft knitted fabric to simulate the interaction between legs and pressure clothing. The finite element model of human fabric is conducive to the development of pressure clothing. Although finite element model has been widely used in the medical field, its establishment is usually based on CT, MRI and other image data processed by reverse engineering software, which has highly personalized characteristics between different individuals. Therefore, using finite element model to predict the experimental results of different individuals has certain limitations.

Made of elastic cotton, the patch can stretch up to 180 percent of its original length. Different stretch lengths produce different tension on users, which can be divided into natural tension, moderate tension and ultimate tension [7]. It can be cut into different shapes as needed, such as I, Y, X, O, claw, lantern, etc., as shown in **Fig 1**. Different shapes have different effects. In clinical treatment, the combination of different shapes of intramuscular adhesive should be selected according to the specific evaluation of the patient's disease, and the appropriate shape and tension should be adopted to achieve the best therapeutic effect.



（a）Ishape （b）Yshape （c）Xshape （d）Claw shape （e）Lantern shape

Fig 1. Cutting and binding method.

In the two clinical trials conducted by Fratocchi[8] and Wong[9] et al., the peak moment of motion of elbow flexure and knee extension were respectively tested. The results showed that compared with the false and unglued groups, the intramuscular effect group could significantly increase the peak moment of elbow flexion and reduce the time to reach the peak moment of knee extension. After treating patients with neck and low back pain with intramuscular effect stickers, Karatas[10] et al. concluded that intramuscular effect stickers are an effective way to reduce neck and low back pain and improve the range of motion and functional performance of neck and low back. At present, although intramuscular effect paste has been proved to relieve muscle pain and spasm, improve trunk motion, treat patelomalacia and other functions, and is widely used in treatment, there are only a few studies on the treatment of ITBS with intramuscular effect paste. Moreover, due to the simple research methods and different pasting methods, further research is needed. At the same time, the research on the effect mechanism of intramuscular effect paste is extremely lacking, and how its shape, combination, tension and binding direction affect the treatment and how to achieve the ideal effect has not been set foot in this field.

Methods : In this study, the intramuscular effect patch design for the adjuvant therapy of iliotibial band syndrome will be conducted, and the lower limb model auxiliary design will be established based on finite element modeling. The subjective and objective experiments will be conducted on the effectiveness of the product, and the effects will be evaluated by electromyographic signal, which is of great significance for preventing and alleviating the occurrence of iliotibial band syndrome and improving muscle function. The research methods are as follows:

1. Literature data method: The topic of intramuscular effect patch design is an important topic involving medical science, biomechanics and other professional fields. In order to further study the application of intramuscular effect patch in the treatment of iliotibial band syndrome, it is necessary to comprehensively consider the pathogenesis and biomechanical characteristics of iliotibial band syndrome, as well as the principle of action and design points of intramuscular effect patch by reading books and journals and combining theoretical research of various disciplines. It provides important theoretical support for the design of intramuscular adhesive for iliotibial band syndrome.

2. Lower extremity static finite element model simulation method: CT scanning machine is used to conduct scanning respectively. Subjects are required to lie flat on the examination table and continuously scan human lower extremity, including pelvis and foot, and save the data in DICOM format. The Mimics interactive medical image control system was used to process the data to obtain the basic model of the lower limb. After the model extracted by Mimics is stored in STL format, there are some problems such as rough surface and bad structure. A series of operations such as patching, noise reduction, smoothing, surface fitting were performed on the model through Geomagic, and meshing was performed through Hypermesh. Abaqus simulation software was used to set boundary conditions and material properties of each organization, and the stress of correction was simulated and analyzed according to the research content.

3. Finite element iliotibial band stress simulation analysis: In finite element iliotibial band stress simulation analysis, this method is used to simulate the stress situation of the lower limb muscle system, and obtain the stress size of the iliotibial band under different protective loads. This simulation technique can quantitatively evaluate the protective effect and provide valuable reference information for researchers. Specifically, the simulation method can simulate the stress of the iliotibial band in motion by applying different loads, and measure its stress response under different loads, so as to provide a scientific basis for protection design. Finite element analysis can effectively predict and evaluate the effect of protective parameters, and provide strong support for the study and treatment of iliotibial band syndrome.

4. Experimental research method of electromyography: time domain analysis and frequency domain analysis of electromyography can detect muscle fatigue. The signals of each muscle of the lower extremities of the subjects before and after applying the intramusynal effect patch were obtained by the electromyographic equipment. The electromyographic signals under various states were analyzed by SPSS to obtain the electromyographic signals during muscle fatigue and analyze the time and characteristics of muscle fatigue. By comparison, it is concluded whether the human lower limb muscles can be relieved from fatigue under the intramuscular effect paste.

Research results: Based on musculoskeletal structure and finite element model establishment of the lower limb, CT data of the lower limb (hip to knee joint) were collected, and the Mimics interactive medical image control system was used to process the data, so as to obtain the basic model of the lower limb and display the coronal view, axial view and sagittal view of the lower limb CT, as shown in **Fig 2.**

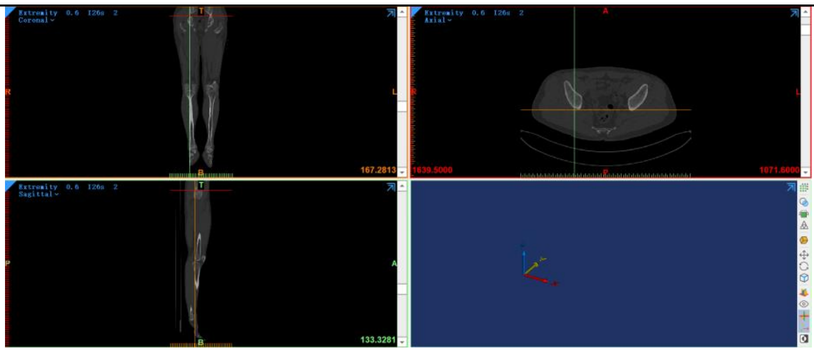
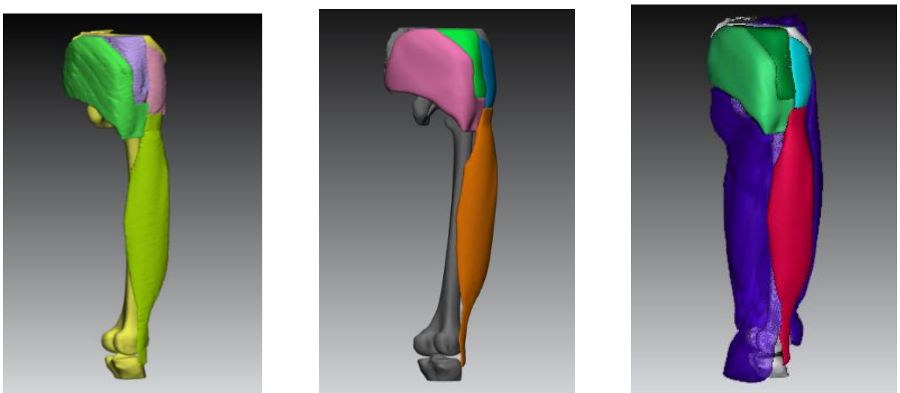


Fig 2. Three views of anatomical plane in CT image

The 3D lower limb model was reconstructed by Mimics and Geomagic reverse engineering, and bone, muscle, and iliotibial band were extracted by threshold segmentation in the Mimics software, as shown in **Fig.3**.



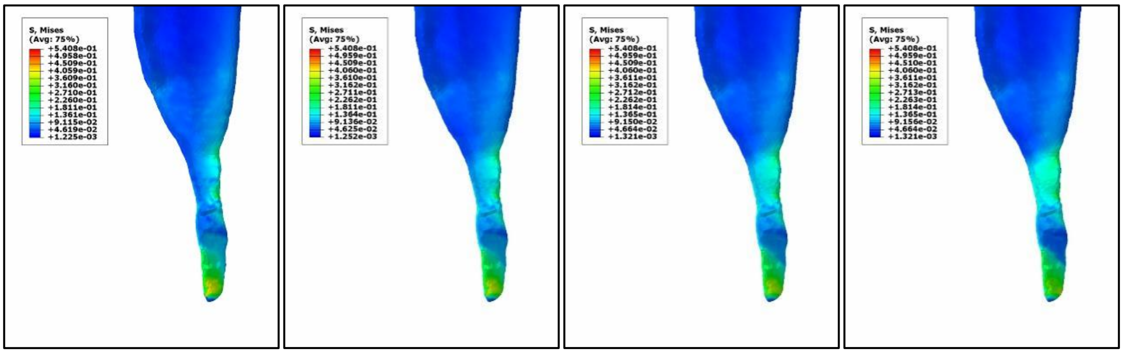
(a)Preliminary extraction (b)optimization model (c)completion of optimization
Fig.3 Reconstruction model

The model was optimized in Geomagic software to generate a solid model, on which the bone, muscle, and iliotibial band were assembled using Solidworks software, and the model was processed using HyperMesh, as shown in **Fig 4**. After the establishment, load was applied to the model to find the optimal pressure, which could provide reference for the design of the later intramuscular effect paste.

Fig 4 Model after grid division

In finite element analysis, the key point is to apply the exact force, so that the correct calculation results can be obtained. In this study, the force of iliotibial band was simulated by applying displacement and pressure load. When determining the size of the applied load, since the intramuscular effect paste is similar to clothing to some extent, the data of clothing pressure is used for the study, and the surface pressure load applied on the skin surface of lower limbs is set as 0, 3.92kpa, 5.88kpa and 7.85kpa [11] [12].

According to the four protective loads selected above, an upward displacement is applied to the iliotibial band as the force during the stretching of the iliotibial band during running, and the stress analysis is performed on it. At this time, the stress range of the iliotibial tract at the contact point between the iliotibial tract and the lateral condenle of femur was 1.811E-1~2.271E-1Mpa, 1.811E-1~2.262E-1Mpa, 9.150E-2~4.664E-2Mpa, and 9.156E-2~4.664E-2Mpa, respectively, as shown in **Fig 5**. Finally, when the pressure was 5.88kpa, the stress value of the contact between the iliotibial band and the lateral condyle of femur was relatively small, which met the requirement of reducing friction. Moreover, the stress distribution was relatively dispersed, and the pressure on the patient was small.



(a) 0 kpa protective load (b) 3.92kpa protective load (c) 5.88kpa protective load (d) 7.85kpa protective load

Fig.5 Stress analysis results

Finite element analysis can effectively predict and evaluate the effect of protective parameters, and provide strong support for the study and treatment of iliotibial band syndrome. Based on these data, an intramuscular patch to relieve the pain of iliotibial band syndrome should apply pressure above the knee and be designed with muscular anatomy in mind.

The iliotibial band is connected to the tensor fascia lata and the gluteus maximus, so these two muscles should be taken into account in the design of the intramuscular effect patch. Type I intramuscular effect patch should be designed on the tensor fascia lata and gluteus maximus to improve muscle performance. The two I and iliotibial bands may merge to form a Y shape. It is also possible to use a loose attachment based on the I shape of the iliotibial band to distribute the stress of the iliotibial band to the side muscles to reduce the tension of the iliotibial band. The lantern patch or octopus patch is used to exert tension on the skin surface of the iliotibial band, thus widening the space of the superficial fascia layer under the skin and enhancing the ability of organizing blood circulation, thus creating a good recovery environment for the muscles and iliotibial band.

In addition to the tensor fascia lata and gluteus maximus, the gluteus medius should also be considered when designing the intramuscular patch. The gluteus medius is not directly related to the iliotibial tract, but because the iliotibial tract is an extension of the gluteus maximus and the tensor fascia lata, it is indirectly synergic with the gluteus medius. When the gluteus medius is weak, it is often accompanied by tension in the tensor fascia lata and gluteus maximus. This leads to tension in the iliotibial band, resulting in iliotibial band syndrome. Therefore, the O-type muscle patch is designed to support the gluteus medius. There is an indirect synergistic relationship between the iliotibial band and the gluteus medius.

Conclusion :

1. This study is mainly aimed at iliotibial band syndrome. Considering the shape of the iliotibial band and the relationship between it and the femoral condyle, a finite element model is established, so as to study how much corrective force the iliotibial band can achieve the best correction effect without affecting the activities of patients.

2. At the same time, it studied the establishment of bone model and muscle model with medical images, proposed a repeatable multi-media model establishment methodology, designed the shape of the intramuscular effect patch by studying the pathogenesis of iliotibial band, applied corresponding force to the model or changed the skin material properties, simulated the intramuscular effect patch and obtained the best effect, and provided references for the subsequent model establishment and product design.

3. The intramuscular effect patch for iliotibial band syndrome designed in this paper based on experimental data has been verified by subjective and objective experiments, laying a foundation for the design of intramuscular effect patch for other soft tissue injuries in the future.

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