

# Research progress in finite element analysis of ankle sprains

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**Abstract:** Ankle dislocation is the most common sports injury and is often associated with sports injuries. Among them, the tendon ligament causes damage to the posterior ankle ligament and the posterior ankle ligament. Important stabilizing structures, especially the anterior fibula ligament and the heelofibular ligament, play an important role in maintaining balance, and their injuries can lead to instability on the lateral side of the ankle. This seriously affects the function of the ankle. At the same time, it has a stabilizing effect on the lower joint, and its damage will also affect the function of the lower joint. [1-2] Foreign scientists have collected cases of acute fractures of the ankle joint, but only the central ligament rupture. Almost all injuries to the central tendon can cause a partial tear of the ligament. However, severe hallux valgus abuse can still lead to isolated damage to the triangular ligament. [3-4] Study surface emography and other techniques for basic ankle fracture studies to address the biomechanical and kinematic problems of ankle sprains. The biomechanics of ankle injuries will now be discussed in conjunction with the mechanisms of ankle injuries. To discuss the biomechanics and kinematics of ankle sprains.

## 1 Introduction

The ankle is the flexor joint of the human body that is most stressed. When standing, the total weight on the ankle when walking is 5 times the body weight. [5] As a result, acute ankle pain is most likely to occur. Injuries in everyday life, cramps around the ankle are the number one cause of joint pain in any part of the body. [6] Approximately 23,000 ankle patients occur every day in the United States. [7] Foot pain is common in clinical practice, but many people overlook them. Poor management can lead to lax ligaments and ankle instability, leading to repeated spasms and future tendencies toward joint pain.

At present, there are three common research methods for the mechanism of ankle injury, the first of which is the most accurate in vivo study. Direct testing of the biomechanical behavior of the human ankle joint is more difficult due to the diversity of the human body and the limitations of human studies; The second is in vitro research of cadaveric tissue, as the body is immersed in disinfectant, the physiological environment has changed, and at the same time, the test results are too dependent on the accuracy of tools and equipment, and the requirements for tools and equipment are high, so the results are very inaccurate. In addition, cadaver samples are difficult to obtain, and the ethical requirements of experiments are high. The third is to establish a three-dimensional anatomical model of the human body and conduct finite element analysis. This method can create a human body model with simple and fast imaging data: the analysis of computer models can accurately

simulate the mechanical environment in vivo by controlling experimental conditions. Therefore, the finite element analysis method was chosen as the primary method to discuss ankle integrity and injury and biomechanical reconstruction.

## 2 Structural composition of the ankle joint

The ankle joint is the main joint of the lower limbs of the human body, which is the elbow joint, and its main function is to support weight. The talus has three articular surfaces that intersect the inner and outer heels and the lower part of the tibia. [8] The main functions of the ankle joint are dorsal and contravective, with greater flexion. When the foot is fixed, some rotation may occur in the heel joint, including abduction and extension. Dorsal flexion often occurs at the same time as abduction, jealousy and addiction. [9] The front of the talus is larger than the top, and when the ankle bends the leg sharply, it is easy to separate the inside and outside. However, this tendency is suppressed by the anterior and posterior hair growth plates of the interossteel and connecting tendons. [10] The nature and location of the retinal ligaments and tendons, as well as the spacer-filled ankle cavity during dorsal flexion, determine greater stability of the ankle joint during dorsal flexion. The interior of the joint begins with the tibia nerve and the peroneal nerve. In total, 13 tendons pass through the joints of the foot. [11]

The finite element method is an important tool for biomechanical research, and its basic principle is to divide the continuous part of infinite particles into finite

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elements, connect between the elements through nodes, and the information between the elements is transmitted through the nodes without loss, and assemble the hardness matrix of thousands of elements into a universal hardness matrix of a continuous part and represent it mathematically. The characteristics of the model are mainly determined by the type of element and the material. The results of the finite element analysis depend largely on the type of element used. When creating 3D models, it is often necessary to fine-tune the model with biomechanical finite elements, reduce the freedom of the model, or simulate more complex structures that are not easily discernible by 3D hardware.

Several ligaments are responsible for stabilizing the ankle joint and can be divided into four groups: the posterior collateral ligament, the lateral inferior ligament, the medial triangular ligament, and the distal tibia-fibula ligament. [12] Posterior ligaments include the anterior ligament of the anterior fibula, the posterior ligament of the anterior fibula, and the heelofla ligament, which primarily repair the posterior ankle at the talus and calcaneum. The anterior fibula ligament is considered the main structure that protects the ankle from forward displacement, internal rotation, and ligaments, and is considered the weakest ligament, which may explain why the anterior fibula ligament is the most common ankle spasm. [13] Injured ankles, thick and strong posterior fibula ligaments help limit internal rotation when the ankle is dorsal flexed; The heelofibular ligament provides stability to the lower joint and is the only force to elevate the leg in a strong inverted structure. [14]

The inferior terrestrial ligament consists of a cervical ligament, an intertextural ligament, a calcane ligament, and an extensor support band. The cervical ligament is the main structure that regulates inverted varus from the lower joint. Rigid, fan-shaped deionized fiber complexes are divided into upper and lower layers. [15] The top layer includes the scaphoid ligament, calcane ligament, and posterior talosis; The deeper layers include the anterior tibial pitch ligament and the posterior tarsal ligament. The anatomy, mechanical environment and function of the ankle joint require the main stabilization of this point. Let your ankles be one of your most fragile joints.

At present, the most widely used research on ankle dynamics at home and abroad is the three-dimensional force plate system. Chu et al. used a 3D force gauge combined with a motion capture system to study kicking movements in motion and obtain ankle varus angles and ground reflections in various movements. Lida et al. used a 3D force platform to simulate ground contact absorption when an athlete jumped to the ground, and noted the influence of central motion control on ankle kinematic parameters. Madigan used a 3D force platform to study the relationship between ground force and lower extremity muscle fatigue and found that lower extremity muscle fatigue before landing affects the extent of lower extremity joint flexion. The stability of the ankle joint is closely related to the degree of fatigue of the muscles of the lower extremities. With in-depth research, it is possible to quantify the level of fatigue in the ankle and ankle muscles, thereby reducing the likelihood of an

ankle sprain.

Currently, there are three common research methods, the first and most accurate of which is the study in humans. Due to the diversity of the human body and the limitations of human studies, it is more difficult to directly test the biomechanical behavior of the human knee joint. [16] The second is the in vitro study of cadaveric tissue. As the body is soaked in disinfectant, the physiological environment changes. At the same time, the test results rely too much on the accuracy of tools and equipment, and the requirements for tools and equipment are very high. So the results are very inaccurate. In addition, cadaver samples are more difficult to obtain. The third is to establish a two-dimensional anatomical model of the human body and conduct finite element analysis. This method can create mannequins with simple and fast imaging data: the analysis of computer models can accurately simulate the mechanical environment in the body by controlling experimental conditions. [17] Therefore, the study of the integrity and damage of the ankle triangular ligament and the reconstruction of biomechanics, including the development of mathematical models of human-machine three-dimensional physical simulations, are the premises of these studies by choosing finite element analysis methods.

The mechanism of ankle injury and mechanical changes is well known, but after surgery or conservative treatment, how to improve the biomechanics and mobility of the ankle joint and how to restore soft tissues such as ligaments, the lack of visualization studies will lead to the hindrance of treatment, so finite element analysis can promote the further development of ankle injury diagnosis and treatment rehabilitation.

Surface electromyography (sEMG) technology is a method that uses electromyography to acquire and analyze electrical signals on muscle surfaces. The use of sEMG for skeletal muscle injury type prediction, strength training evaluation, muscle injury detection, reaction time measurement, exercise time and electromagnetic delay of human activity and its relationship with muscle tissue metabolism have significant effects. Lida et al. found that surface electromyography was used to study lower extremity muscle coordination and confirmed the role of central motor control in landing coordination. Sterberg et al. studied ankle muscle fatigue in repeated calf elevation tests. It was found that it was not the maximum muscle strength that limited the movement of the calf, but the inability to maintain a specific range of motion due to muscle fatigue. There is some degree of correlation between surface EMG activity and muscle activity and function, which may partly reflect neuromuscular activity.

At present, the three-dimensional force measuring plate system is widely used in ankle dynamics research at home and abroad. Chu et al. used a 3D dynamometer combined with a motion capture system to study kicking in motion, and obtained ankle varus angle and ground reflection in various movements. Lida et al. used 3D force platform to simulate the ground contact absorption when athletes jumped to the ground, and pointed out the

influence of central motion control on ankle kinematics parameters. Madigan used 3D force platform to study the relationship between ground force and lower limb muscle fatigue, and found that lower limb muscle fatigue before landing will affect the range of lower limb joint flexion. The stability of ankle joint is closely related to the fatigue degree of lower limb muscles. Through in-depth study, the fatigue degree of ankle and ankle muscles can be quantified, thus reducing the possibility of ankle sprain.

### 3 Outlook

With the increase of research results, the research hotspots are changing, from the initial experimental research to the clinical decision-oriented scientific research perspective. The research on tibial prosthesis inclination, femoral malrotation, comparison of lateral meniscus allograft approaches and evaluation of material properties in knee arthroplasty has attracted scholars' attention. It can be seen that the development of finite element research in assisting knee arthroplasty and transplantation will be the future trend. It can be seen that the finite element analysis method will play an important role in promoting the innovation of knee implant materials, the research on biomechanical properties of joint prosthesis and the development of computer-assisted surgery technology, and will also be the development trend in recent years. The exploration of surgical prosthesis, approach and materials, it is speculated that the research on materials, prosthesis properties, assisted knee replacement, transplantation and other repair technologies will become the future development trend in this field.

The mechanism of ankle injury and mechanical changes is well known. However, after surgery or conservative treatment, the lack of visual research on how to improve the biomechanics and mobility of ankle joint and how to restore soft tissues such as ligaments will lead to the obstruction of treatment methods. Therefore, finite element analysis can promote the further development of diagnosis and treatment of ankle injury.

At present, the biomechanics and kinematics research of ankle sprain mostly focus on the analysis of static mechanics and dynamic movement of athletes, such as running and jumping. This makes it difficult to advance the research. How to combine the above-mentioned science and technology, how to analyze the overlap best, and how to calculate the damage rate from objective measures are worthy of careful study. In addition, the current biomechanical and kinematic research provides a practical perspective and benefit for the basic research of ankle injury. It is believed that with the progress of science and technology, its application in ankle injury will become more and more obvious, and more and more general finite element evaluation tools will appear.

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