FINITE ELEMENT ANALYSIS OF ELITE RACE WALKERS' LIGAMENT DAMAGE AROUND THE ANKLE ON TALUS STABILITY

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ABSTRACT

Objective: *Through analyzing ligament damage around the ankle of elite race walkers, impact of damage on talus stability was analyzed. Methods: Through analysis of 3,200 injured race walkers from physical culture institutes and sports teams in a city, who were injured during June 2012-June 2015, the impact of ligament damage around the ankle on talus stability was analyzed, ankle injury was analyzed with spiral CT scan data, and three-dimensional aggregation model of foot and ankle was built with three-dimensional reconstruction software.*

Results: *The three-dimensional finite element models of normal human foot and ankle were built. Internal and external rotation of ankle cause different effects on biomechanics of talus.*

Conclusion: *Under external rotation forces, tibiotalar ligament of athletes will exert important impact on stability of ankle.*

Keywords: *Elite, Race walker,Ankle; Ligament injury, Talus; Stability, Finite element.*

DOI: 10.19193/0393-6384_2018_3s_244

Received *January 30, 2017;* ***Accepted*** *March 20, 2018*

Introduction

Walking race is a sport with relatively high requirement for ankle strength. During walking race, serious damage to ligament around the ankle can be caused. Ligament injury around the ankle will cause a certain impact on stability of talus in mortise. When athletes have ligament damage around the ankle, anatomical position of talus in mortise will undergo serious change, which thus exerts a serious impact on contact area of athletes' ankle, causing lesions to athletes. The author adopted three-dimensional finite element method to observe ligament damage caused by forces of inner and external rotation state, and then studied contact stress of ankle, made effective analysis of biomechanical characteristics of talus after ligament injury around the ankle, so as to make effective diagnose of ligament injury around the ankle, and take necessary treatment measures on the basis.

The paper selected 3,200 race walkers with ligament injury around the ankle from different physical culture institutes and sports teams for effective analysis.

Method

General Information

The athletes participating in the study appeared varying degrees of ligament injury around the ankle. Wherein, 1,678 are male athletes who are averagely 170 centimeters tall and weigh 60 kg or more, and 1,522 are female athletes who are averagely 156 centimeters tall and weigh 48 kg or more. X-ray examination of injured athletes conducted and foot tumor malformation is excluded.

Establishment of Finite Element Model

With CT scan, we imported the data into three-dimensional reconstruction software,conduct effective analysis of athletes' bone tissue and soft tissue with threshold value, and help athletes build an aggregation model of structure around talus. The procedural output file is STL file. Then we imported reverse engineering software to Geomagic Studiu10.0, and performed smoothing of system model. Based on geometrical form of various articular surface of ankle, we divided cartilage boundaries on the surface of bone, and eventually fitte NURBS surface, so as to effectively output Iges format. Then, the finite element pre-processing software Hyperwork10.0 can be imported, and the cartilage can be conveniently formed in the same manner. Based on Jabil data of athletes' gray joint ligament, we connected ligament attachment point in three-dimensional arrangement of five fiber bundles, and then established corresponding ligament model, eventually realizing mesh generation of solid model. Figure 1 below shows three-dimensional finite element model.

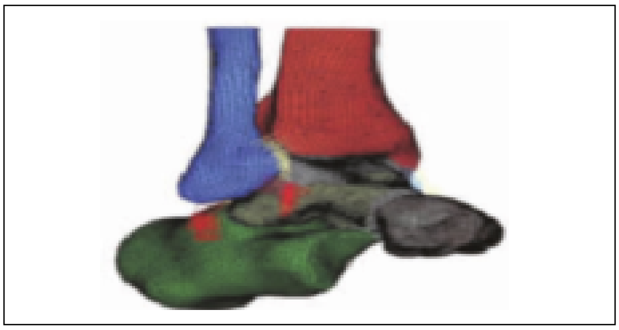

Figure 1: Three-dimensional finite element model.

Convenient Conditions and Loading Condition of Ankle

In this study, it is assumed that when athletes' ankle is in a neutral position, ligament around then ankle will not be loaded, with miles at zero. Under external rotation state, it is difficult to simulate loading condition of medial ligament injury. After selection of simulation group, external rotation torque of upper segment of tibia and fibula was about 10 nanometers. We simulated loading condition of lateral ligament injury under inner rotation state. Before simulation of foot rotation, torque of upper segment of tibia and fibula was 10 nanometers. We restrained cranial base in longitudinal direction, as well as the upside and bottom of distal surface of navicular bone[1]. For athletes' ankle in walking movement, static load method was adopted to study its force condition relatively static load method, with force loaded on the tibia and fibula interface, and coefficient of friction at this time as hundredth.

Observation Standards

We studied talus Von Mises stress changes and displacements under different loads on athlete's angle. Based on talus structure of athletes, we effectively measured the apply force on the ankle joint surface, and took effect force of ankle surface as an important observation index.

Results

In the present study, we built three-dimensional finite element models for normal foot and ankle such as human cartilage and ligament, wherein there are more than 73,385 units and more than 21,870 joints, which are all in valid set similarities. In addition, it can calculate stress value of ligament around the ankle, contact stress of articular surface of talus during ligament injury around the ankle under internal rotation and external rotation of ankle, as shown in Table 1 below.

Torsion	ATiF	PTiF	ATaFi	PTaFi	CaFi	ATiTa	PTiTa	TiNa	TiCa
Internal rotation	6.09	0	0	3.28	18.91	7.16	0	36.3	5.21
External rotation	1.15	4.59	13.75	0	0	0	5.42	0	8.04

Table 1: stress distribution of ligament around astragalus under internal rotation and external rotation (MPa)

When race walkers have ligament injury around the ankle, they will have significant pain which will be strengthened during movement. The injured side often has obvious tenderness reaction. During lateral ankle ligament injury, more than half of athletes have anterolateral ankle tenderness with mobility degree, with serious tenderness between TDC and BDC of calcaneofibular ligament and obvious tenderness at point of fracture of ligament. Drawer test (Figure 2 below) of front ankle of injured athletes appears positive, and ankle varus stress test appears positive[2-4].

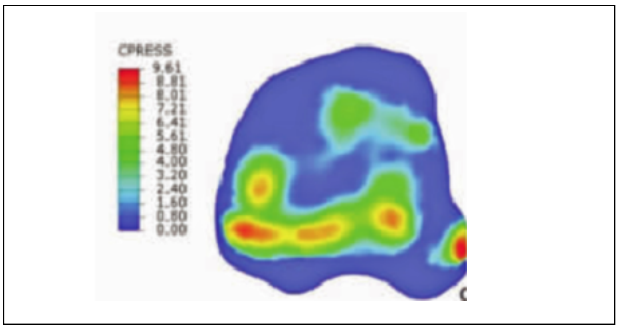

Figure 2: Contact pressure diagram (MPa) of tibial articular surface after medial ligament injury of an athlete.

During lateral collateral ligament injury of ankle, there will be medial malleolus pain. In addition, after race walkers have ankle ligament injury, their ankle tends to have serious swelling which is the most obvious at injured side of athletes. When race walkers have ligament injury around the ankle, subcutaneous soft tissue damage will occur, which results in capillary rupture, serious ecchymosis and bruising on injured side of athletes.

During diagnosis of race walkers' ligament injury around the ankle, the causes for athletes' injuries should be understood, and foot posture during injury means a great help for diagnosis of ligament injury around the ankle(5). Ankle three-dimensional finite element analysis method has significant meaning in diagnosis of ligament injury around the ankle(6). After the occurrence of ligament injury around the ankle, integrity of talus and its surrounding structures will greatly impact the stability of athletes' ankle. Biomechanics changes in the ankle can be passed through changes in talus load(7-9). Ligament injury around the ankle will cause very important impact on stability of talus in mortise(10). From theperspective of traditional mechanics, experimental analysis has achieved remarkable results.

However, these findings fail to have a valid understanding of different forces of athletes. Three-dimensional finite element analysis can make necessary finite element calculation of connecting ligament attachment points in three-dimensional arrangement of 5 fiber bundles based on anatomical data of ligament around the ankle. Calculation results of the process can effectively reflect regional mechanical characteristics, and reflect information of global nature to some extent, which enables effective digital analysis of three-dimensional data possible. The digital analysis is visual, intuitive qualitative analysis(11-13).

Medial ankle ligament is also known as deltoid ligament in clinics. Deltoid ligament of the body is divided into four major components, namely tibionavicular ligament, tibiocalcanean ligament, posterior talotibial ligament and anterior talotibial ligament. Deltoid ligament tissue is important tissue that ensures stability of human ankle joint. Shallow deltoid ligament of the body mainly controls talus extorsion, while deep deltoid ligament injury will cause great change in talus movement in all directions(14). Lateral ligament of the ankle joint is composed of three main parts including calcaneofibular ligament, anterior talofibular ligament and posterior talofibular ligament. There exists a close relationship between passive stability of lateral joint and integrity of body articular surface and accessory ankle ligament. In ankle injury cases of race walkers, a majority is lateral collateral ligament injury. In all lateral collateral ligament injury, patients with acute lateral collateral ankle ligament injury accounts for considerable proportion(15). With the differences in length and intensity of athletes' lateral ligament v, there is also significant differences in degree of injury(16). Necessary analysis of ligament injury around the ankle is of very important positive significance to maintaining the stability of athletes' ankle(17-19). The X-ray image of ankle ligament injury of an athlete is shown as Figure 3.

Figure 3: Drawer test diagram of ankle.

Discussion

In summary, on the basis of CT image sequence, this study built a three-dimensional finite element model for talus of the foot and surrounding structures under normal gait, which can faithfully reflect impact of gray joint injury on stability of surrounding ligament. However, in the course of study, myotility around the ankle was neglected, which constituted some flaws in the research. In future course of research, continuous improvement is needed to make research results more perfect.

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Acknowledgement
Jilin Social Science Fund Project - Research on the health industry of the elderly (No. 2017M16).

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