Statistical shape model analysis of Chinese heel bones

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INTRODUCTION: The heel is an important weight-bearing part of the human body, during walking and running, the heel bone bears about 5.4 and 11.1 times of the body weight [1]. Due to the high physiological load, about 10% of fractures occur in the foot, and the heel fractures may have long-term negative effects on the patient's function and comfort, and even lead to disability [2,3].Studying the anatomical morphology of Chinese heel bones can help explain the injury mechanism of Chinese heels and provide a basis for the diagnosis of heel mechanical injuries. Statistical shape model (SSM) is a mathematical method that can be used to analyze the morphological characteristics of human bones, but there is no SSM analysis result of Chinese heel bones (calcaneus, talus). Therefore, this study aims to construct the SSM database of Chinese calcaneus and talus, and analyze the skeletal morphological characteristics of Chinese calcaneus and talus.

METHODS: A total of 30 subjects were recruited in this study, with an average age of 30.1±12.9 years and an average BMI of 23.8±3.4 kg*m-2. The subject was in the supine position, and both feet were scanned by CT (intraslice resolution 512*512, voxel space size 0.6*0.6*1mm). The unilateral feet of the subjects were randomly selected, and the three-dimensional surface models of the calcaneus and talus were reconstructed using Amira (Thermo Fisher Scientific, USA). The surface models of the calcaneus and talus were smoothed using Matlab, and the left and right foot models were mapped to the right by mirroring, and re-divided into a uniform size mesh (about 20,000 nodes). Select a moderately sized and representative model as the reference model [4], align all models to the reference model through non-rigid registration, and resample all calcaneus and talus models based on the number of nodes and node connections of the reference model. The average shape model, principal component vector (PC) and feature weights of the calcaneus and talus were obtained using principal component analysis (PCA), and the influence of PC1-3 in the calcaneus and talus SSM on the surface morphology was analyzed.

RESULTS: The proportions of the top three principal components of the calcaneus are: PC1 (14.59%), PC2 (11.62%), and PC3 (8.88%), and the total proportion of the top three principal components is 35.09%. Among them, the size of the medial surface of the calcaneus is correlated with PC1, negatively correlated with PC2, and positively correlated with PC3; The size of the lateral bone surface is negatively correlated with PC1 and positively correlated with PC3; the anterior talar articular surface is positively correlated with PC1 and negatively correlated with PC3; the middle talar articular surface is positively correlated with PC3 and negatively correlated with PC1; the posterior talar articular surface is positively correlated with PC1 ; The anterior process of the calcaneus is positively correlated with PC2 and negatively correlated with PC3; the medial process of the calcaneal tuberosity is positively correlated with PC and negatively correlated with PC1 and PC3; the lateral process of the calcaneal tubercle is negatively correlated with PC1 and positively correlated with PC3; The back of the bone is positively correlated with PC1 and PC3 and negatively correlated with PC2; the back of the calcaneus is positively correlated with PC1 and negatively correlated with PC2 and PC3; the articular surface of the cuboid calcaneus is positively correlated with PC2 and negatively correlated with PC3; The tendon groove is negatively correlated with PC1 and positively correlated with PC3; the plantar surface of the calcaneus is negatively correlated with PC1 and PC2, and positively correlated with PC3.

The proportions of the first three principal components of the talus are: PC1 (39.48%), PC2 (7.76%), and PC3 (6.28%), and the total proportion of the top three principal components is 53.52%. The size of the trochlear of talus was positively correlated with PC1, and correlated with PC2 and PC3; the heel articular surface was negatively correlated with PC1, PC3, and positively correlated with PC2; the posterior process of the talus was positively correlated with PC1, PC3; the lateral process of the talus was positively correlated with PC1, and negatively correlated with PC2 Correlation; Talar neck is negatively correlated with PC1, positively correlated with PC2; Talar groove is positively correlated with PC1, negatively correlated with PC2, PC3.

DISCUSSION: In this study, the surface shape of the Chinese calcaneus and talus was analyzed by the SSM method, and it was found that PC1-3 of the calcaneus affects the medial surface of the calcaneus, the anterior, middle, and posterior talar articular surfaces, the anterior process of the calcaneus, and the medial and lateral processes of the calcaneal tubercle. , the back of the calcaneus, the back of the calcaneus, the articular surface of the cuboid calcaneus and the morphology of the flexor hallucis longus tendon groove of the calcaneus. PC1-3 of the talus affects the shape of the talus trochlea, heel articular surface, talus kyphosis, talus lateral process, talus neck and talus groove. Planar X-ray and optimization, using fewer principal components to achieve fast individualized 3D model reconstruction.

SIGNIFICANCE/CLINICAL RELEVANCE: Establishing a statistical shape model of the Chinese heel bone plays an important role in the diagnosis of ankle joint diseases, the study of ankle kinematics and the mechanism of ankle joint injury.

References: [1] Giddings, V. L., Beaupré, G. S., Whalen, R. T., & Carter, D. R. (2000). Calcaneal loading during walking and running. Medicine and science in sports and exercise, 32(3),627–634. [2] Robinson, K. P., & Davies, M. B. (2015). Talus avulsion fractures: Are they accurately diagnosed?. Injury, 46(10), 2016-2018. [3] Melenevsky, Y., Mackey, R. A., Abrahams, R. B., & Thomson III, N. B. (2015). Talar fractures and dislocations: a radiologist's guide to timely diagnosis and classification. Radiographics, 35(3), 765-779. [4] Audenaert, E. A., Van Houcke, J., Almeida, D. F., Paelinck, L., Peiffer, M., Steenackers, G., & Vandermeulen, D. (2019). Cascaded statistical shape model based segmentation of the full lower limb in CT. Computer methods in biomechanics and biomedical engineering, 22(6), 644-657.

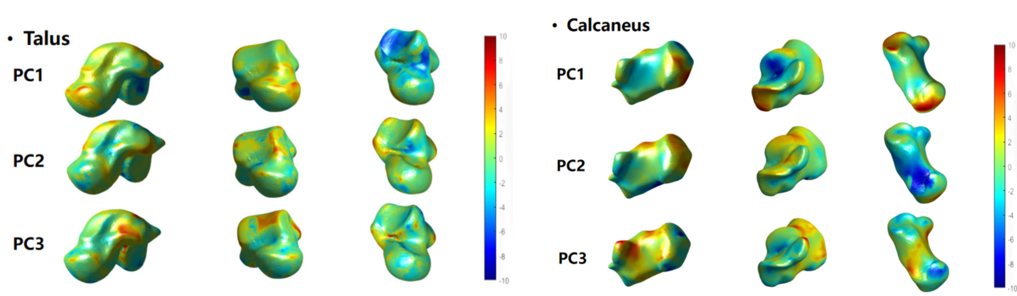

Figure 1. Principal component analysis results of the talus and calcaneus (unit: mm)