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JOINT CONGRUENCY AND DISTANCE ANALYSIS OF THE SUBTALAR JOINT DURING WEIGHT-BEARING

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INTRODUCTION: Recent studies have suggested that the subtalar joint plays a key role in the development of ankle joint osteoarthritis (OA). However, current literature fails to report on the morphological characteristics of the subtalar joint. Statistical shape modeling (SSM) facilitates 3D visualization of morphological bone differences within a population, identifying mean shape and shape modes of variation based on correspondence particle locations. Our previous study established talus and calcaneus morphological modes of variation using SSM [1]; however, subtalar joint morphology interactions such as joint congruency or distance were not analyzed. Few studies have examined subtalar joint space, reporting six-nine averaged regions within the articular surfaces in a weight-bearing position [2]. Joint space distance has been investigated in the past, but to our knowledge quantitative descriptions of 3D subtalar joint congruency are not available for healthy or symptomatic populations [3]. Understanding the subchondral bone morphology of the subtalar joint and the underlying joint congruency and distance interaction could help to better understand the role of the subtalar joint in case of ankle osteoarthritis. Subtalar joint congruency and distance analyses could also provide clinicians with tools to assist in pre-operative planning for procedures such as post-traumatic repair of calcaneal fractures. We sought to analyze the joint congruency and joint space distance interaction of the subtalar joint at each correspondence particle on the articular surfaces in the SSM. Utilizing these correspondence particles will provide us with a more continuous evaluation of subtalar joint morphology with the ability to link joint morphology findings to individual bone variability.

METHODS: Twenty-seven asymptomatic controls (age: 50.0 ± 7.3 years; height: 169.4 ± 6.4 cm; BMI: 25.3 ± 3.8 kg/m2; 7 males) previously underwent weight-bearing CT scans (Planmed Verity; 0.4 x 0.4 x 0.4 mm voxels) with IRB approval. For each participant, CT images were segmented to create 3D models of the talus and calcaneus (Amira, v6.0.1, Visage Imaging). For each participant the articulating surfaces (posterior and anteromedial facets) were isolated using the 2nd principal of curvature and a joint coverage calculation which identified regions of intersecting normal vectors. Then, identified articular surface nodal data points were used to calculate joint space distance, mean curvatures, and Gaussian curvatures for all participants using PostView (v2.1.0, FEBio Software Suite, University of Utah). Each participants' talar model was compared with the SSM mean talar shape to determine common correspondence particle locations across all individuals. Joint congruency and distance were calculated at each correspondence particle across the population and viewed using MATLAB (MATLAB, R2017b, MathWorks, Natick, MA, USA). Congruency was rated from 0 to 1, with 0 being perfectly congruent.

RESULTS SECTION: In our healthy population during a weight-bearing position, the posterior facet demonstrated an uneven joint space with a larger medial distance (~3.5mm) that gradually narrowed to a smaller lateral joint space (~1.5mm). The anteromedial facet demonstrated an even joint space (~1.5mm) across the articular surface (Figure 1). However, both the posterior and anteromedial facets were evenly congruent throughout the articular surface with an average congruence index of 0.22 ± 0.05 and slight variation around the perimeter of the posterior facet (Figure 1). The congruence index and joint space distance for each participant was consistent with the reported mean trends (see a representative individual in Figure 2).

DISCUSSION: Studies evaluating shape models of the subtalar joint have assessed the joint space and morphological differences of isolated bones without investigating the congruency of the joint. Our study found that joint space distance differed within the posterior facet and congruency was relatively even throughout. We have observed substantial anatomic variation in the talar posterior process, calcaneal pitch and calcaneal facet anterior/posterior slope in our SSM models, yet despite these shape variations, congruency remains very consistent, in this healthy population (Figure 2). Surface morphology of the anteromedial facet is flatter when compared to the curved posterior facet surface and may provide additional stability to the medial column of the foot under weight-bearing conditions. Investigating congruency during dynamic activities would provide additional biomechanical insight concerning the role of the subtalar joint. Future studies should investigate morphological changes in patients having ankle OA in terms of changes in joint congruency and joint space distances during weight-bearing and dynamic activities. The long-term goal is to establish a clearer relationship between altered morphology of the subtalar joint to improve treatment of patients suffering from degenerative changes of the ankle joint.

SIGNIFICANCE/CLINICAL RELEVANCE: Data herein establish normative measurements of joint space and joint congruency throughout the subtalar joint. Future studies will compare these normative measurements to those quantified in patients with pathology to improve diagnosis and treatment decision making.

REFERENCES: [1] Lenz, A. et al. ORS. 2019. [2] Siegler, S. et al. J Biomech. 2018; 76:204-211. [3] Ateshian, G. et al. J. Biomech. 1992; 25:591-607.

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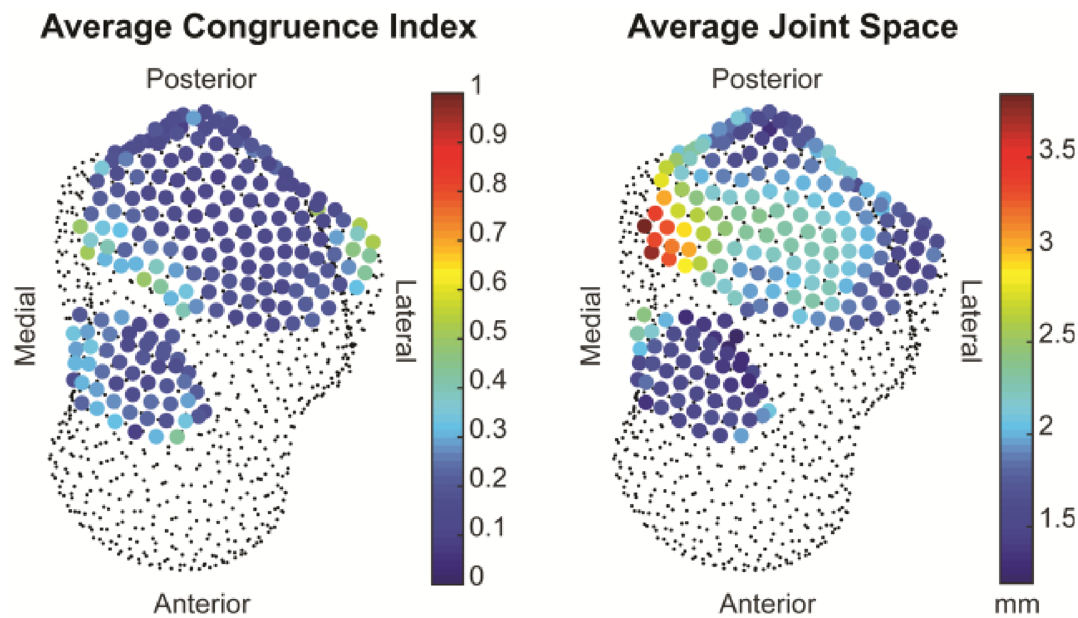

Figure 1: Talar mean shape correspondence particles with anteromedial and posterior facet data visualized from the inferior aspect of the talus. Left) Average subtalar joint congruence index across all individuals with congruency rated from 0 to 1, 0 demonstrating perfect congruence. Right) Average subtalar joint space distance across all individuals.

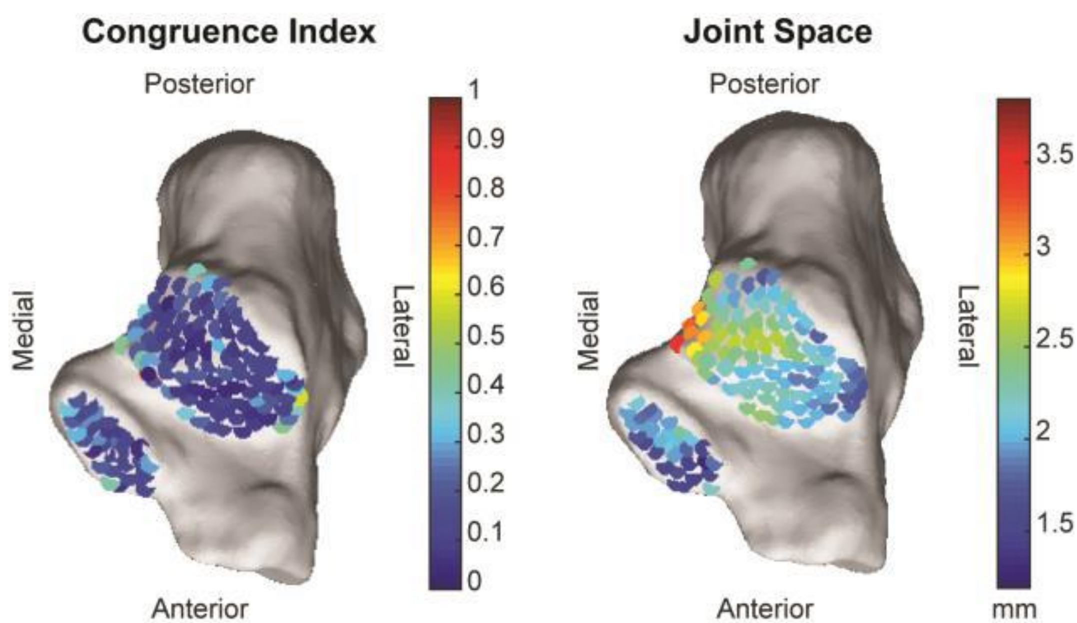

Figure 2: A representative patient joint congruency and joint space distance analysis visualized on the individual's specific calcaneus. The data for this individual is consistent with our mean findings. Left) Anteromedial and posterior facets show an even congruence index with slight variations on the edges of the posterior facet. Right) Joint space distance of the posterior facet increases from lateral to medial, while the anteromedial facet remains relatively even.