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Knee joint kinematics during walking influences the spatial cartilage thickness distribution in the knee

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ABSTRACT

The regional adaptation of knee cartilage morphology to the kinematics of walking has been suggested as an important factor in the evaluation of the consequences of alteration in normal gait leading to osteoarthritis. The purpose of this study was to investigate the association of spatial cartilage thickness distributions of the femur and tibia in the knee to the knee kinematics during walking. Gait data and knee MR images were obtained from 17 healthy volunteers (age 33.2 ± 9.8 years). Cartilage thickness maps were created for the femoral and tibial cartilage. Locations of thickest cartilage in the medial and lateral compartments in the femur and tibia were identified using a numerical method. The flexion–extension (FE) angle associated with the cartilage contact regions on the femur, and the anterior–posterior (AP) translation and internal–external (IE) rotation associated with the cartilage contact regions on the tibia at the heel strike of walking were tested for correlation with the locations of thickest cartilage. The locations of the thickest cartilage had relatively large variation (SD, 8.9°) and was significantly associated with the FE angle at heel strike only in the medial femoral condyle ($R^2 = 0.41, p < 0.01$). The natural knee kinematics and contact surface shapes seem to affect the functional adaptation of knee articular cartilage morphology. The sensitivity of cartilage morphology to kinematics at the knee during walking suggests that regional cartilage thickness variations are influenced by both loading and the number of loading cycles. Thus walking is an important consideration in the analysis of the morphological variations of articular cartilage, since it is the dominant cyclic activity of daily living. The sensitivity of cartilage morphology to gait kinematics is also important in understanding the etiology and pathomechanics of osteoarthritis.

1. Introduction

The factors influencing the phenotypic thickness variation in the articular cartilage at the knee is an important consideration in understanding pathomechanics of degenerative disease such as osteoarthritis. It has been suggested that the joint loading conditions during normal activities can affect knee articular cartilage morphology (Andriacchi et al., 2004a; Jones et al., 2000). While it has been reported that loading during activities such as walking influence the medial–lateral variations in bone density (Hurwitz et al., 1998) and cartilage thickness (Miyazaki et al., 2002), the kinematic factors that affect variations in cartilage thickness are still not well understood. Yet, the regional sensitivity of cartilage morphology is important, since it has been suggested that the kinematic changes at the knee can lead to osteoarthritis (Andriacchi et al., 2009).

The mechanics of walking offer the opportunity to test the relationship between gait mechanics and cartilage, since patterns of movement and loading are repeatable (Kadaba et al., 1989). For example, axial knee joint loading for normal walking has three peak amplitudes during the stance phase of gait (Schipplein and Andriacchi, 1991) with a large force at heel strike. It has also been shown (Koo and Andriacchi, 2008) that the anterior–posterior (AP) position of contact on the medial and lateral compartment of the knee changes during the heel strike phase of walking and can be related to a unique combination of knee flexion, AP position and internal–external (IE) rotation.

The loading and kinematic conditions that occur at heel strike during walking offer a unique opportunity to test for a relationship between regional cartilage thickness and individual variation in the kinematics of the knee during walking. Specifically, it would be important to know if healthy cartilage is adapted to normal kinematics during walking, since it has been suggested that kinematic changes

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