Gait Pattern Changes and Knee Osteoarthritis

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Introduction
Modern gait analysis offers the unique means to measure the biomechanical response to diseases of the musculoskeletal system during activities of daily living. In particular, knee osteoarthritis (OA) is a musculoskeletal disease that is strongly linked to mechanical factors (i.e. joint loading and alignment) that can be measured by gait analysis. The importance of the adduction moment was highlighted by Hurwitz et al.(1998) who demonstrated a link between the adduction moment and proximal tibial bone distribution in a group of normal subjects. Sharma et al. (1997) reported differences in the adduction moment between severe OA patients and early OA patients. More subtle discrimination of gait pattern changes may be possible by examining more than a single gait measure such as the adduction moment. Multivariate statistical techniques offer the ability to examine gait pattern differences described by multiple kinematic and kinetic gait measures (Chau, 2001). Identifying the mechanical factors of gait associated with knee OA is important in understanding the initiation and progression of OA as well as in planning therapeutic interventions. The objective of this study was twofold: (i) to discriminate between normal subjects and knee OA patients using quantitative gait analysis and pattern recognition techniques, and (ii) to study the association between biomechanical factors and radiographic changes associated with early OA.

Methods
Gait analysis was performed on a group of 54 patients with knee OA prior to total knee replacement, and on a group of 59 elderly (55-80 yrs) asymptomatic subjects. Furthermore, frontal and sagittal knee radiographs were obtained and scored according to radiographic features of osteoarthritis (Scott et al., 1993). The gait system was used to calculate three dimensional knee joint angles, moments and forces resulting in nine gait measures represented as waveform data (Li et al., 1993). The gait measures were analysed using pattern recognition techniques to discriminate between the OA and normal subjects. The most important features from each of the nine gait measure was extracted using principal component (PC) analysis (Deluzio et al., 1997). Mathematically, principal component analysis consists of an orthogonal transformation, which converts the time-normalized waveforms into new uncorrelated principal components. These components are optimal in the sense that they explain a maximal amount of variance. The first three PCs were obtained from each of the nine gait measures. This resulted in a set of 18 parameters that were used in a stepwise linear discriminant analysis to determine the optimal separation between the osteoarthritic and the normal subjects.

Results & Discussion
The PC analysis identified the features of the gait waveform data that could discriminate between the normal and OA patients. The most discriminatory gait measures (and the PCs) were found to be the flexion angle (second PC), the adduction moment (first two PCs), and the flexion moment (second PC). The analysis of the flexion angle data is shown in Figure 1. Eight of the asymptomatic subjects were classified as having a gait pattern similar to the OA patients (abnormal). Seven of these asymptomatic subjects had radiographic osteoarthritis according to Scott’s radiographic score. Furthermore, the severity of the radiographic score was related to the degree of gait abnormality.

A large percentage of elderly people have radiographic evidence of osteoarthritis while only a portion of these will develop symptomatic osteoarthritis. These data suggest that dynamic loading and alignment may help explain this link. This is the first study to demonstrate such a link in subjects with pre-symptomatic, early OA.
Figure 1. The PC analysis of the flexion angle waveform data. A The flexion angle waveform data during level walking for a group of elderly asymptomatic subjects (blue) and a group of subjects with knee osteoarthritis (red). B. The two groups are clearly separated by the PC2 score. C The loadings for the first two PCs. These loading vectors are applied to each subject’s waveform data to produce the two scores. PC1 is an average level of the flexion angle during the gait cycle and PC2 contrasts midswing (~70%) with late stance (~40%), and initial/final foot contact (0%, 100%). D Two subjects are shown with a high (blue) and a low (red) PC2 score which indicates that PC2 corresponds to the knee joint range of motion.

References


