THE LOADING RESPONSE PHASE OF THE GAIT CYCLE IS IMPORTANT TO KNEE OSTEOARTHRIS

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INTRODUCTION

The pathogenesis of knee osteoarthritis (OA) is complex and involves many correlated biological and mechanical factors. Modern gait analysis is used to calculate mechanical measures such as knee joint loading and orientation, which play a substantial role in the progression of OA. Previous studies have reported several differences in gait measures with knee OA, such as higher adduction moments and lower ranges of motion in the sagittal plane. (Kaufman, 2000) However, these studies can be difficult to interpret due to the numerous individual measures reported. (i.e. joint angles, moments, stride characteristics) There are interrelationships between the time-varying and constant gait variables measured, as well as with other parameters related to knee OA. (i.e. obesity) Important biomechanical features of OA may lie in the relationships between these variables, undetectable in univariate analyses.

The objective of this study was to detect biomechanical factors of knee OA using a multidimensional analysis technique that simultaneously considered multiple time varying and constant gait measures, and other parameters important to knee OA.

METHODS

Three-dimensional gait analysis was performed on a group of 54 elderly patients with severe knee OA, and a group of 63 elderly asymptomatic subjects. Three components of knee joint angles, moments and forces were calculated with the QGAIT gait analysis system. (Costigan, 1992) For each subject, the static Hip Knee Ankle (HKA) angle, the standing knee flexion angle, and the medial and lateral condyle joint spaces were measured with QPR, a standardized X-ray technique (Siu, 1991). Body Mass Index (BMI) was also calculated. The full gait cycle data of the 9 waveform gait measures and the 5 constants were simultaneously included in a principal component analysis (PCA). This multivariate statistical technique was used to extract the major features of variation in the original gait data. A subset of features that cumulatively explained at least 90% of the original data variation was retained. A backwards elimination stepwise discrimination procedure was employed to determine the subset of retained features that optimally separated the normal and OA groups of PC scores. A linear discriminant function was defined as a linear combination of the discriminatory features identified with the stepwise procedure. The discriminant function (i) represented the optimal boundary of separation between the two groups of PC scores and (ii) provided the discrimination power of each feature. The most discriminatory PCs were interpreted in terms of the relative contribution of each of the 9 waveforms and 5 constants, and the relative importance of each percentage of the gait cycle.

RESULTS

The multidimensional analysis technique successfully identified discriminatory gait features, with a cross-validation misclassification error <8%. A hierarchy of the features was determined through inspection of the linear discriminant function.

Feature 1, the most discriminatory feature, had major contributions from several alignment-related measures such as the adduction moment, the static HKA alignment angle in the frontal plane and the lateral-medial joint force. It described a multidimensional alignment difference between the groups during the stance phase of the gait cycle.

The twentieth feature extracted in the principal component analysis was the second most important feature in the multivariate discrimination of the normal and knee OA subject groups. Early stance, or loading response, was completely isolated as the portion of the gait cycle important to this feature, the loading response feature (Figure 1). The most significantly contributing gait measures to this feature included body mass index (BMI), medial-lateral knee joint force, gait velocity, and the flexion moment. Subjects with a larger BMI value had a greater tendency to be classified as OA. Interestingly, a Student’s t-test revealed that there was not a significant univariate difference in the BMI parameter between the two groups. The loading response feature was a multidimensional gait phenomenon. Having only a large BMI was not sufficient to classify a subject as having an osteoarthritic gait pattern. The gait pattern change described by the loading Response Feature was a time-dependent difference that involved several contributing gait measures during loading response.

Figure 1: PC20 isolates the loading response phase of gait.

DISCUSSION

The multidimensional gait analysis technique detected a very discriminatory feature that described an interesting gait pattern change with knee OA during the loading response phase of the gait cycle. Loading response has been hypothesized to be important to the disease process of knee OA. In 1992, Messier et al. identified significantly larger loading rates during loading response in 15 patients with moderately severe knee OA. In 1991, Radin et al. identified an impulsive foot-ground reaction at heelstrike in subjects with mild, activity-related knee pain, presumably consistent with pre-OA. This rapidly applied loading was speculated to be provoking joint damage and creating osteoarthritic changes within the knee.

The Loading Response Feature was a multidimensional gait phenomenon because it described a very important difference between normal and knee OA gait patterns involving the interaction of a number of gait measures throughout loading response. The importance of BMI, a relative obesity measure, to the feature also confirmed the utility of including parameters in the analysis.

The importance of the loading response phase to knee OA had been hypothesized previously, and this study quantitatively identified a discriminatory gait pattern mechanism that occurred during loading response.

REFERENCES