BIOMECHANICAL MECHANISMS OF KNEE OSTEOARTHRITIS

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INTRODUCTION

Knee Osteoarthritis (OA) is a metabolically active disease of the musculoskeletal system that has no definitive cure and produces substantial societal cost. The pathomechanics of knee OA are poorly understood, largely due to the progressive and multifactoral nature of the disease process. Treatment options for persons with moderate levels of knee OA have therefore been limited to pharmacological and therapeutic interventions of unknown effectiveness. Numerous risk factors for the disease have been identified, and mechanical factors have been linked to the progression of the disease. However, little attention has been paid to how these risk factors interact to progress the disease.

METHODS AND PROCEDURES

The anterior-posterior and lateral radiographs of the affected knee of 40 subjects diagnosed with moderate, medial-compartment knee OA were assessed by an experienced orthopaedic surgeon with a visual analog severity score (VAS), representative of the radiographic severity of the joint. Gait analysis was performed for all subjects, and three-dimensional joint angles and net external moments at the hip, knee and ankle joints were calculated. Surface electromyography (EMG) was simultaneously recorded from two hamstrings, two gastrocnemius and three quadriceps muscles. Principal component analysis (PCA) was applied to each joint angle and moment and the EMG waveforms for each muscle separately to extract major patterns of variation of the waveforms. A stepwise regression analysis was used to obtain the subset of biomechanical variables that best explained radiographic knee OA disease severity, defined by the visual analog severity (VAS) score.

RESULTS

Five variables were selected as optimal for the prediction of the VAS, including (in order) the knee adduction moment PC1, the medial gastrocnemius PC2, BMI, the ankle adduction angle (i.e. the toe out angle of the foot) PC2, and the ankle rotation moment PC3. The total variation explained ($R^2$) by this five variable model was 67.4%. Separately, only the knee adduction moment PC1 had a significant but mild univariate correlation with VAS ($r^2=0.214$).

High severity was associated with high overall magnitudes of the knee adduction moment during stance (Figure 1a), a phase shift in peak activation of the medial gastrocnemius muscle towards later stance and an increase in activation of the muscle in late stance (Figure 2), high BMI, a greater and more sustained toe out angle of the foot relative to the tibia during mid to late stance (Figure 1b), and a greater net resultant eversion moment of the foot mid-stance.
DISCUSSION

The results of this study suggest that the role of biomechanical factors in the radiographic progression of knee OA is multivariate in nature. Radiographic disease severity within a moderate knee OA subject group was well explained by a multifactorial combination of biomechanical changes ($R^2 = 67.4\%$). The knee adduction moment, which is the gait variable most associated with knee OA disease progression (Miyazaki et al., 2002), was important only in combination with other biomechanical changes (Figure 1a). Obesity also consistently emerges as a risk factor in the onset and progression of musculoskeletal conditions (Felson, 1992), but the mechanism of its role in the pathomechanics of knee OA has remained unclear. These results support previous findings that its role is multivariate in nature (Astephen and Deluzio, 2004). Also included in the severity model were changes in ankle joint biomechanics during gait (Figure 1b), which are suggestive of a mechanism to move the line of action of the ground reaction force more laterally during mid-stance. The fifth factor in the prediction model represented an abnormal neuromuscular control strategy of the gastrocnemius muscles (Figure 2) which may represent a mechanism to provide frontal plane stability to the diseased joint.

SUMMARY

The radiographic severity of a moderate knee OA population was well explained by a combination of obesity, gait and neuromuscular changes. The mechanism defined by the model should be studied further with longitudinal and simulation studies to understand its potential role in the initiation and progression of disease and to develop more appropriate early diagnostic and treatment strategies for patients with moderate knee OA. These results highlighted the importance of considering multiple factors simultaneously in the study of knee OA, and the need for more multivariate biomechanical analyses that include information from multiple joints and neuromuscular information from electromyography.

REFERENCES


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