In Vivo Knee Kinematics during Gait Associated with Knee Osteoarthritis Severity

INTRODUCTION

Knee osteoarthritis (OA) is a degenerative disease that may be triggered by biomechanical and mechanical insults. Gait analysis has been conducted to clarify the biomechanical characteristics of knee OA. However, most previous studies examined patients with different stages of knee OA as a single population and compared them with asymptomatic subjects as controls. Since the kinematic characteristics of gait change with the development of the disease, it is difficult to identify the stage-specific biomechanical changes caused by degenerative changes in the joint and compensatory motion. Additionally, physical function (i.e., muscle strength, ROM, and alignment) is also thought to contribute to the changes in kinematic gait variables that reflect the development of knee OA.

The purpose of this study was to investigate the kinematic gait variables of the knee joint that enable the distinguishing of normal healthy subjects from subjects with knee OA at each stage of degenerative change (early, moderate, and severe). Another aim was to examine the relationships between the kinematic gait variables of the knee joint that reflect the development of knee OA and the physical function (muscle strength, ROM, and alignment) of the knee.

METHODS

Forty-two patients with knee OA and 13 healthy young subjects were recruited. All subjects were examined while stationary in the standing position and while walking on a 10-m walkway at a self-selected speed. An 8-camera high-speed motion analysis system (Motion Analysis Corp.) was used to three-dimensionally record the lower-limb movements. In each trial, we calculated the angular displacements of flexion/extension, abduction/adduction, and external/internal tibial rotation by using the point cluster technique [1] during the stance phase of gait. We calculated each variable at the time of foot contact, 50% of stance phase and angular excursion during 50% stance phase. In OA patients, we also measured muscle strength (i.e., concentric muscle torque of the knee extensors and flexors and isometric strength of hip abduction and adduction), ROM (i.e., hip flexion, hip extension, hip internal rotation, hip external rotation, knee flexion, knee extension, ankle plantarflexion, and ankle dorsiflexion), and alignment (i.e., Q-angle and navicular drop).

One-way ANOVA was used to test the difference in OA severity and those in knee kinematics variables between OA patients and normal subjects. OA severity was determined on the basis of the Kellgren-Lawrence grade: grades 1 and 2 indicated early OA; grade 3, moderate OA; and grade 4, severe OA. The alpha level was set at \( p < 0.05 \). The associations between the knee kinematics variables and muscle strength, ROM, and alignment were analyzed by using Pearson’s product moment correlation coefficient. The alpha level was set at \( p < 0.01 \). The protocol was approved by the Institutional Review Board of National Rehabilitation Center for Persons with Disabilities.

RESULTS

Figure 1 shows the mean time-course comparisons across OA severities for the 3 angular displacements of the knee (abduction/adduction, external/internal tibial rotation, and flexion/extension). The flexion angle at the time of foot contact in the severe OA patients (mean (SD) = 5.3° (4.3°)) was significantly less than that in the normal subjects (11.6° (5.0°)) and early OA patients (11.0° (5.7°)) (\( p < 0.01 \) for both), and this angle in the moderate OA patients (6.4° (3.5°)) was significantly less than that in the normal subjects (p < 0.01). The abduction angle at the 50% stance phase in the severe OA patients (-3.7° (1.6°)) was significantly less than that in normal subjects (-1.4° (1.5°)), early OA patients (0.0° (2.4°)), and moderate OA patients (-1.0° (2.3°)) (\( p < 0.05 \), \( p < 0.01 \), \( p < 0.01 \), respectively). The excursion of tibial rotation in the early OA patients (11.1° (3.5°)) was significantly less than that in the normal subjects (16.4° (3.6°)) (p < 0.05).

Moderate positive correlations were found between the knee flexion angle at foot contact and ROM of hip extension (\( r = 0.43 \)) and hip internal rotation (\( r = 0.42 \)). Moderate positive correlations were also found between the knee abduction angle in the 50% stance phase and the ROM of hip internal rotation (\( r = 0.44 \)), knee flexion (\( r = 0.42 \), Figure 2a), and ankle plantarflexion (\( r = 0.39 \)). Further, moderate positive correlations were found between the excursion of tibial rotation and ROM of knee extension (\( r = 0.38 \), Figure 2b).

DISCUSSION

The results of this study revealed that knee OA patients have characteristically different knee kinematics depending on the level of disease progression. Early OA patients demonstrated decreased excursion of tibial rotation during gait, which was associated with restricted ROM of knee extension. In early OA, this restricted ROM of knee extension may influence the screw-home movement and thereby decrease the excursion of tibial rotation during gait. Moderate OA patients demonstrated decreased knee flexion during gait, which was associated with restricted ROM of hip extension and internal rotation. This result agrees with that of a previous study [2] that showed a decreased knee flexion angle and moment in moderate OA. Severe OA patients demonstrated increased knee adduction during gait, which was associated with restricted ROM of hip internal rotation, knee flexion, and ankle plantarflexion. In severe OA, instability of knee adduction during gait is increased, and the progress of degenerative changes induces joint contracture during knee flexion. In the moderate and severe OA patients, the ROM of hip or ankle was associated with the knee kinematics during gait. It is thought that in these stages, the kinematic chain during gait between the knee and hip joint and the knee and ankle joint should be considered during treatment. In conclusion, the characteristic differences in knee kinematics depending on knee OA severity and the related physical function should be considered in order to care for and prevent knee OA progress.

REFERENCES