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The Knee

Relationships between the center of pressure and the movements of the ankle and knee joints during the stance phase in patients with severe medial knee osteoarthritis

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ABSTRACT

Background: The knee joint movement during the stance phase is affected by altered ankle movement and the center of pressure (COP). However the relationships between changes in the center of pressure (COP) and the altered kinematics and kinetics of the ankle and knee joints in patients with osteoarthritis (OA) of the knee are not well understood. The purpose of this study was to determine the relationships between changes in the COP and the altered kinematic and kinetic variables in ankle and knee joints during the stance phase in patients with medial knee OA.

Methods: Fourteen patients with knee OA (21 knees) and healthy subjects were assessed by gait analysis using an eight-camera motion analysis system to record forward and lateral shifts in the COP and the angle and net internal moments of the knee and ankle joint. Spearman rank-correlation coefficients were used to determine the relationship between these results.

Results: In knees with medial OA, lateral shifts in the COP were correlated with knee flexion angle. Lateral shifts in the COP were correlated with the second peak of the knee extensor moment and correlated with the knee abductor moment.

Conclusions: In patients with medial knee OA, lateral shifts in the COP were negatively correlated with the kinematic and kinetic variables in the sagittal plane of the knee joints. Controlling such lateral shifts in the COP may thus be an effective intervention for mechanical loads on the knee during the stance phase in patients with knee OA.

1. Introduction

Walking is an important movement for transporting the body during daily life. Impaired walking ability limits the activities of daily life [1]. Functional disorders of the lower joints can impair walking ability, especially when the functional stability of the knee joint, controlled by muscles and ligaments, is disrupted by structural changes. Such changes can result in a marked reduction in walking ability. Osteoarthritis (OA) of the knee is an age-related degenerative disease that leads to structural and functional failure of the knee joint caused by degeneration of the joint cartilage, formation of bone osteophytes, meniscal injury, ligamentous injury, muscle weakness, and a limited range of motion. These changes result in pain, which is the most common complaint made by those suffering from knee OA [2,3].

Patients with knee OA often change their walking patterns to minimize pain. For example, they decrease their walking speed [4], reduce the number of steps taken [5], and/or decrease their walking rate [6]. An increase in the external knee adduction moment is characteristic of the stance phase for knee OA with varus deformity, which increases the load on the medial compartment of the knee joint. In such cases, those with knee OA and varus deformity use methods such as toe-out [7] and trunk lean [8] to decrease the external knee adduction moment. Changes in the kinematics and kinetics of the knee joint during the stance phase of gait in patients with knee OA include decreases in the range of motion (flexion–extension) [9] and in the vertical component of the ground reaction forces [10]. These changes are compensatory tactics in order to decrease knee pain during the stance phase.

In one study using gait analysis for knee OA that focused on other parts of the lower extremities, Fisher et al. [11] reported that the plantar-flexor moment of the ankle joint during the terminal stance phase decreased in the presence of knee OA. Because this plantar-flexor moment contributes to the forward progression during the terminal stance [12], a decrease in this moment caused a decreased walking

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Table 1
Characteristics of the knee OA group and the control group.

Valuables	OA group	Control group
Age	77.0 ± 7.5	31.8 ± 6.1
Height (m)	1.53 ± 0.97	1.68 ± 0.12
Weight (kg)	59.6 ± 13.1	65.2 ± 10.7
BMI (kg/m^2)	25.1 ± 3.5	22.9 ± 2.3
Femoro tibial angle (unit:degree)		
KL grade 3 (4 knees)	181.0 ± 1.2	
KL grade 4 (17 knees)	184.5 ± 3.4	
Range of motion (unit:degree)		
KL grade 3 (4 knees)	122.5 ± 10.4	
KL grade 4 (17 knees)	126.8 ± 11.6	

Femoro-tibial angle: 180° or more indicates varus knee.
Range of motion indicates the flexion angle of the knee joint.

speed and affected the mechanical loads on the knee joint during the terminal stance [13]. Ota et al. [14] also reported that a restricted ankle dorsiflexion angle caused changes in the kinematics and kinetics in the sagittal and frontal planes of movement of the knee joint during the terminal stance phase. The ankle dorsiflexion angle and plantar-flexor moment are easily altered by the center of pressure (COP) during the stance phase. If the COP approaches the toe during the stance phase because the moment arm to the ankle joint is longer than normal, the plantar-flexor moment is increased, causing the tibia to lean forward, which also increases the dorsiflexion angle. Despite these findings, the relationships between the changes in the COP and alterations in the kinematics and kinetics of the ankle and knee joints in patients with knee OA are not well understood.

The purpose of the present study was to evaluate the gait in knees with OA and varus deformity to assess changes in the COP and in the angle and internal moments of the ankle and knee joints during the stance phase. We hypothesized that lateral shifts in the COP during the stance phase caused by medial knee OA alter the knee flexion–extension angle and knee abductor moment. We also hypothesized that forward progression in the COP during the stance phase in OA knees is decreased because of restricted dorsiflexion and a decreased plantar-flexor moment in the ankle.

2. Materials and methods

2.1. Subjects

The subjects enrolled in this study were orthopedic patients visiting the hospital for outpatient treatment of medial knee OA. The patients all had a clinical history of Kellgren–Lawrence (KL) [15] grades 3 or 4 as classified by an orthopedic surgeon. X-rays were performed on the knee OA patients using Rosenberg's position for loading by radiological technologist. An orthopedic surgeon read the X-rays for all patients. The OA knees assessed included 21 knees in 14 subjects (five men, nine women) with the following characteristics (mean ± SD): 77.0 ± 7.5 years old, 1.53 ± 0.09 m height; 59.6 ± 13.1 kg weight; 25.1 ± 3.5 kg/m^2 BMI, and a KL grade of 3 or 4 in at least one knee. The exclusion criteria were prior knee replacement surgery, rheumatoid arthritis, or unresolved injuries to any joints of the lower extremities. Ten subjects (six men, four women) without knee pain with daily activities were classified as control subjects. The characteristics of the knee OA patients and control subjects are shown in Table 1. The protocol for this study was approved by the Ibaraki Prefectural University of Health Sciences Ethics Committee.

2.2. Instrumentation

Kinematic data were obtained at 200 Hz using an eight-camera motion analysis system (Vicon Nexus, Oxford, UK),and the ground reaction force data were recorded at 200 Hz using a floor-mounted force plate (Kistler Instruments, Winterthur, Switzerland). The global coordinate system was defined with the X-axis as anterior, the Y-axis as lateral, and the Z-axis as vertical.

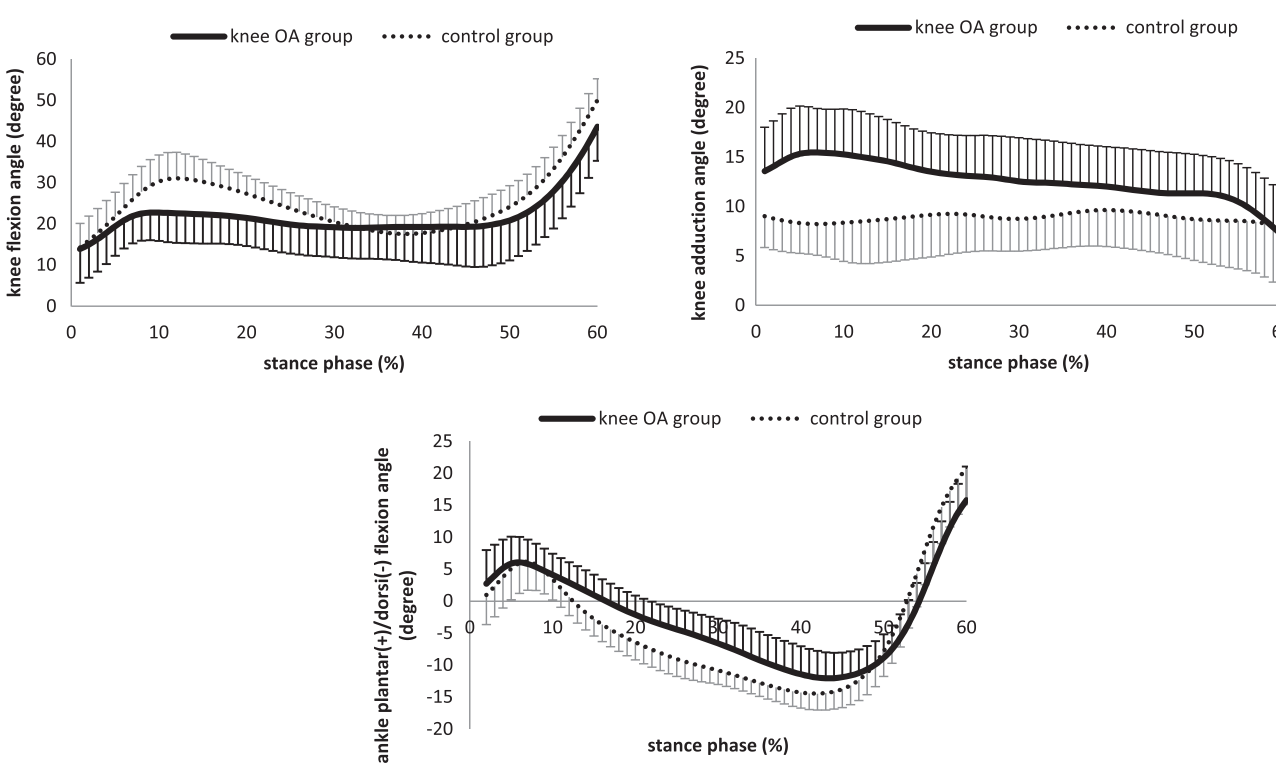

Figure 1. Longitudinal data for the knee and ankle joints angles during the stance phase of knee OA and control groups. Upper: knee flexion–extension (left) and adduction–abduction (right) angles. Lower: ankle plantar-dorsiflexion angles. The vertical lines indicate standard deviations.