INTRODUCTION

Osteoarthritis (OA) is the most prevalent form of arthritis in the elderly. It is estimated that 9% of men and 18% of women over age 65 have knee osteoarthritis (Davis et al. 1991). Individuals with knee OA experience pain, stiffness, and decreased range of motion of the joints. These symptoms significantly limit an individual’s ability to rise from a chair, stand comfortably, walk, or climb stairs. Accordingly, these patients compensate to minimize joint loading and resultant pain. Therefore, the purpose of this study was to analyze the gait characteristics of subjects with knee osteoarthritis. The hypothesis tested was that the knee kinematics and kinetics would be significantly lower than normal in this population.

METHODS

This study was performed on 139 adults diagnosed with knee OA. There were 47 males and 92 females in the study population. The subjects ranged in age from 30 to 82, and had a mean age of 57 years (±12.5). Their mean weight was 85 kg (±17) and their mean height was 167 cm (±9.7). The patients needed to have chronic stable (6-month) pain and stiffness in one or both knees during weight-bearing activities with the involved joint as the primary factor limiting physical or functional activity along with radiographic signs of hypertrophic changes, marginal spur formation, subchondral sclerosis or cyst formation, or nonuniform joint space narrowing. Patients with ligamentous instability >Grade I, knee flexion contractures >5°, inflammatory arthritis, or major lower extremity joint surgery, e.g. knee arthroscopy, were excluded.

As a basis for comparison, 20 healthy subjects were also for comparison with the patients. This group consisted of 9 males and 11 females. Subjects ranged in age from 20 to 42 and had a mean age of 30 (± 8). Their mean weight was 75 kg (± 17) and their mean height was 173 cm (± 11). These subjects had no history of knee osteoarthritis, knee instability, or major lower extremity joint surgery. These individuals had normal strength, full range of motion of the lower extremities, and no neurologic deficits.

The walking conditions studied were those most commonly encountered during activities of daily living (Morlock et al. 2000), namely: level walking, ascending stairs, and descending stairs. Kinematic parameters were acquired with a computerized motion analysis system utilizing six video cameras (Expertvision-Motion Analysis Corporation, Santa Rosa, CA). A set of 21 reflective markers was placed on the body of each subject as described by Kadaba et al. (Kadaba et al. 1989). The subject walked along a 12 meter walkway. Stair ascent and descent was done without using a railing on a flight of four, 18-cm high stairs with a 25 cm run. The first and second steps were independently attached to two separate force plates (Kistler Instrument Corp., Amherst, NY; model 9281B) and were structurally independent from the remaining stair structure (Yu et al. 1996). A commercial software program, OrthoTrak 4.0 (Motion Analysis Corp., Santa Rosa, CA), was used to calculate the joint kinematics and kinetics. The knee joint moments were normalized to body weight and body height and were expressed as net internal moments.

The SAS Statistical Analysis System (SAS Institute, Inc., Cary, NC) was used for data analysis. A repeated measures Analysis of Variance was used to test for significant differences in velocity, joint angles, and gait cycle between the normal subjects and the patients with OA. A repeated measures Analysis of Covariance was used to control for differences in gait velocity when making comparisons for the knee moments. Statistical differences were defined as significant at the α = 0.05 level.

RESULTS

The knee flexion angle on stairs was greater than on level ground (Figure 1). The maximum knee flexion angle for the patients with OA did not differ significantly from the flexion angle for able-bodied subjects (p=0.12). There was no significant difference in the time of maximum knee flexion for all three walking conditions (p=0.44). The subjects with OA walked slower than the normal subjects. These differences in walking velocity were statistically significant (p<0.01).
The patients with OA had a significantly reduced knee peak extension moment compared to the normal subjects (p=0.02) (Figure 2). The timing of the maximum knee extension moment did not differ significantly between the two groups (p=0.07). Similarly, the knee flexion angle at the peak moment was not significantly different between the two groups (p=0.64). The internal adduction moment was significantly increased in the patients with OA (p=0.02). The internal abduction moment (Figure 3), flexion moment and rotational moments were not significantly different between the two groups.

Gender differences were identified in the patients with OA. The female subjects had a significantly greater (p=0.0001) peak knee flexion while there was no significant difference in the time of peak knee flexion. There was no significant difference (p=0.35) in walking velocity between the female and male OA subjects. The female OA subjects generated significantly greater (p=0.01) peak knee extension moments (Figure 4). The normal female subjects also generated greater knee extensor moments than the normal male subjects, but the difference was less significant (p=0.07). There were no other significant differences for the OA subjects or the normal subjects, except for a greater external rotation moment.

All the subjects in this study were at normal weight or overweight. Only 17.3% of the subjects could be considered of normal weight. The rest of the subjects could be considered overweight (38.8%), obese (37.4), or severely obese (6.5%). As the BMI increased, the knee extension moment decreased. Thus, individuals with increased BMI demonstrated a greater compensation to reduce joint loading by reducing the knee extension moment.

**DISCUSSION**

Walking is a common functional activity of daily living. This study provides meaningful information on gait adaptations used by patients with knee osteoarthritis. The subjects with OA...
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attempted to minimize their pain by reducing the knee extensor moment. These adaptations provide pain
relief from dynamic joint loading encountered during gait. The contact forces in the knee joint are
proportional to the net external reaction moment. A large internal moment, needed to balance a large
external moment, will produce a large contact force. Further, it can be noted that the highest extension
moment occurred while descending stairs. The results of this study agree with other studies that show
the demands of stair walking produce larger external moments (Andriacchi et al. 1980; Kowalk et al.
1996). However, these other studies have all been performed on able-bodied individuals.

Female gender is a significant risk factor for OA. Among those over age 65 years, the
prevalence of symptomatic knee arthritis in women is twice the rate in men (Davis et al. 1991). The
exact etiology for this difference in prevalence is unknown. Female subjects had significantly greater
knee extensor moments than their male counterparts. This increased knee loading may be partially
responsible for the increased prevalence of OA in females.

Studies have emphasized the importance of dynamic knee joint loads using the external knee
adduction moment. A greater adduction moment corresponds to increased load on the medial
compartment relative to that of the lateral compartment (Schipplein et al. 1991). Further, studies of
subjects with knee OA have shown that radiographic disease severity (Sharma et al. 1998) are related to
the peak external knee adduction moment. The peak external knee adduction moment in these other
studies is equivalent to the internal knee abduction moment in this study. The present study did not
demonstrate a significant difference in the knee internal abduction moment between normal subjects
and patients with OA. Moreover, the patients with OA had lower moments than the normal subjects. An
explanation for this difference may be the stage and location of osteoarthritis studied, body-mass index
of the subjects, the gait velocity, or differences in the biomechanical model used.

Osteoarthritis has been regarded as a “wear and tear” or “degenerative” condition. Overweight is
a strong risk factor for disabling knee osteoarthritis (Manninen et al. 1996). Studies have demonstrated
that individuals with an increased BMI are at an increased risk of developing knee osteoarthritis
(Schouten et al. 1992; Hochberg et al. 1995; Manninen et al. 1996; Felson et al. 1997). This study
confirms these previous studies, since most of the subject population (82%) would be considered
overweight. In addition, this study demonstrated that individuals with OA and an increased BMI have
gait patterns that deviated farther from normal. Knee loading is related to body mass, and thus,
bio mechanical stresses are magnified in overweight subjects.

Subjects with OA compensate to reduce the knee extensor moment, and consequently the knee
joint loading. By analyzing a patient’s gait pattern, it is possible to define relevant quantitative criteria
for judging the locomotor handicap caused by osteoarthritis. This data can be used to assess the
therapeutic effectiveness of nonsurgical interventions. Nonsurgical treatments for OA which are
effective will result in a reduction in symptomatic pain and increased knee loading as indicated by an
increased knee extensor moment.

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REFERENCES