INTRODUCTION: While total knee arthroplasty (TKA) reliably reduces pain and consistently provides functional knee range of motion, quadriceps weakness and reduced functional capacity are present even at a year after surgery. The purpose of this investigation was to determine the relationship between quadriceps weakness and function after TKA when patients are discharged from outpatient rehabilitation. We hypothesized that (1) knee flexion at heel strike in gait would be higher and knee excursion during weight acceptance would be less in the involved leg compared to the uninvolved, (2) knee moments will be lower in the involved compared to the uninvolved leg during the weight acceptance phase of gait and sit-to-stand (STS) and hip moments will be lower in the involved lower extremity compared to the uninvolved during sit-to-stand, 3) higher integrated EMG activity in the involved quadriceps will show a positive correlation with larger joint excursion in gait, and (4) the amount of symmetry between legs in quadriceps strength will be strongly and positively correlated with the amount of symmetry in knee flexion during weight acceptance in gait, symmetry in vertical ground reaction force in standing, and the distribution of lower extremity extension moments in standing.

METHODS: Fourteen patients with unilateral, end-stage knee OA were tested three months after primary TKA. The mean age at time of operation was 62 years (range 53-74 years) and subjects had an average body mass index (BMI) of 29.7 (range 22.4-37.5). Quadriceps strength was measured using a burst-superimposition technique where a supramaximal burst of electrical stimulation was superimposed on a maximum voluntary isometric contraction (MVIC). Comprehensive motion analysis testing of walking and a sit-to-stand (STS) task was performed using a three dimensional, six camera motion analysis system (VICON 512, MCam cameras, Oxford Metrics, London, England). Two force plates (Bertec Corp, Worthington, OH) were positioned in the floor to capture two successive strides during walking and to assess the ground reaction forces for each leg during sit-to-stand transfers. Active surface electrodes were taped over the mid-muscle belly of the vastus lateralis, biceps femoris, the anterior tibialis, the medial head of the gastrocnemius, the soleus. This study was supported by the Human Subjects Review Board and all subjects gave informed consent.

For STS, the height of the chair was set to the height of the subject’s knee joint line. The subjects position on the chair was standardized and they stood from the chair at a self-selected pace. One practice trial was used to confirm understanding of verbal instructions and the mean of five trials were used for analysis. Subsequently, gait trials were continuously collected until the subject had 10 trials with only one foot on each force plate and speed was maintained within 5% of practice speed.

Sagittal plane hip, knee and ankle joint angles were calculated using rigid body analysis (Visual3D, Version 2.84, C-Motion, Inc., Rockville, MD). Joint kinetics were calculated using inverse dynamics, and are expressed as net internal moments normalized to body mass and height. In walking, each trial’s stance time was normalized to 100% of weight acceptance defined as the time from heel strike to peak knee flexion. In STS, each trial’s standing time was normalized from the start of standing to the end of stand. The signal for the EMG data was sampled at 1080 Hz. This linear envelope created using a phase corrected filter with a low pass cutoff frequency of 20Hz was normalized to the maximum signal obtained during the MVIC trials or during dynamic contractions during the walking or STS trials. The integral of the quadriceps activity during the loading response during walking and during sit-to-stand was used for analysis.

RESULTS: In gait, the involved knee had a significantly lower knee flexion angle during weight acceptance (p=0.02) which was correlated to quadriceps muscle activity (r=0.54, p=0.06). During STS, subjects shifted weight away from the operated limb(p<0.01). Quadriceps muscle activity and the extension moments at the knee and hip were smaller in the involved compared to the uninvolved (p<0.01). The amount of asymmetry in knee excursion during weight acceptance in gait (r=0.70, p<0.01) (Figure 1) and the uninvolved hip extension moment during STS was related to the amount of asymmetry in quadriceps strength (r=0.61, p=0.02) (Figure 2), the more symmetrical a subject was in quadriceps strength the more symmetrical they where in the distribution of moments between hips.

DISCUSSION: Quadriceps weakness is a significant impairment that plays an important role in functional outcomes after TKA. Subjects with TKA adopted a strategy of movement which allowed the uninvolved limb to compensate for involved quadriceps weakness during functional tasks as opposed to a potential alternate strategy of increasing the recruitment of the involved quadriceps. Quadriceps strength influenced lower extremity loading in a way that could alter the wear of the prosthesis and progression of osteoarthritis in the major weight bearing joints of the lower extremity. Quadriceps weakness in patients with TKA has a substantial impact on the movement patterns and performance of the knee during functionally important tasks. Better outcomes in the involved quadriceps strength may result in a more balanced amount of load between limbs. Altered movement patterns related to quadriceps weakness have implications regarding potential exercise prescription, wear of the prosthesis, and progression of osteoarthritis in the uninvolved leg.

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