Quantifying the Relationship between Pre-Operative Knee Joint Function during Gait with Improved Joint Function Due to Primary TKA.

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Introduction: Total knee arthroplasty (TKA) surgery is the primary treatment option for those presenting with severe or end-stage knee osteoarthritis (OA), with the aim to increase functional capacity of the knee joint, reduce the pain associated with the disease and increase the patient’s quality of life. It has been shown that TKA surgery does improve knee joint kinematics and kinetics towards asymptomatic patterns, but not fully and variability between patients post-operatively remains (Hatfield et al., 2011). It has also been shown that discrete sagittal plane kinematic and kinetic gait metrics pre-operatively are highly predictive of their associated value post-operatively (Smith et al., 2006). Although, there is little evidence as to what degree a patient stands to improve knee joint function during gait post-operatively, as compared to pre-operatively, or whether subjects displaying more reduced gait function pre-operatively stand to gain the most increase in knee joint level function post-operatively. The objective of this study was to quantify the relationship between pre-operative joint-level function during gait, with the improvement of function due to primary TKA.

Methods: 46 patients (17 males, 29 females) diagnosed with severe knee OA and scheduled for primary TKA surgery underwent a 3D gait analysis (NDI OptotrakTM 3020, AMTI force platform) 1 week prior to, as well as 1 year after, their TKA. 3D joint kinematics and kinetics were calculated consistent with the joint coordinate system model (Grood and Suntay, 1983), with knee flexion/extension about the transepicondylar axis, internal/external rotation about the long axis of the tibia, and adduction/adduction about a floating axis perpendicular to the flexion and rotation axes. Five gait trials were collected then averaged per subject at their self-selected walking speeds and normalized to 100% of the gait cycle. The subjects received 1 of 3 implant designs during their TKA surgery (non-randomized), distributed as: 21 Zimmer NexGen PS (Zimmer, Warsaw, IN), 12 Stryker Triathlon PS (Stryker Corporation, Kalamazoo, MI), and 13 Stryker Triathlon CR.

Discrete metrics, previously reported in the literature (Astephen et al., 2008), of gait mechanics were calculated using MATLAB (MathWorks Inc., Natick, MA, 20014) for each subject from both the pre-operative and post-operative gait data. A change score was then calculated for each metric between the two time points. Two-tailed Pearson correlation coefficients were calculated using SPSS (IBM Corp., Armonk, NY, 2012) to test for significant linear associations between pre-operative knee joint gait metrics and their associated change scores. The percentage of subjects, per metric, within a standard deviation of asymptomatic values (mean +/- 1 standard deviation) at both the pre-operative and post-operative time points was also calculated, along with the respective percent change between time points.

Results: Subject demographics are included in Table 1. The TKA cohort used was representative of other TKA cohorts shown in the literature, having both a higher BMI and older age than our asymptomatic cohort (N = 60) (Astephen et al., 2008). Table 1 also reports all mean and standard deviations of
calculated discrete gait metrics for the asymptomatic group, and the TKA group at both the pre-operative and post-operative time points, along with each associated change score.

Significant (p < 0.05) negative correlations were found (Table 1) between all preoperative metrics and their associated change score. The minimum knee adduction moment at mid-stance was found to have the highest significant correlation (R = -0.87, p < 0.001), found in Figure 1, followed by peak knee flexion angle (R = -0.81, p < 0.001) and the 2nd peak of the knee adduction moment (R = -0.81, p < 0.001). Mean waveforms with associated standard deviation bands for both preoperative and postoperative knee kinetics along with knee flexion angle during gait are shown in Figure 2. The percentage of subjects within +/- 1 standard deviation of the asymptomatic means for the calculated gait metrics are also included in Table 1. All metrics pre-operatively contained a percentage of subjects within asymptomatic values, with the 1st peak knee adduction moment (41.30%) and the minimum knee flexion moment during early-stance (34.78%) having the highest. Almost all metrics saw an increase in the number of subjects post-operatively, except the minimum knee flexion moment during late-stance which saw no change. The 2nd peak of the knee adduction moment and the minimum knee flexion moment during early-stance had the highest increases of subjects between time points, with an increase of 45.65% and 26.09% respectively. Gait kinematic variables all showed less than 50% of the cohort not within the one standard deviation range of asymptomatic, as well as the mid-stance knee adduction moment, late stance extension moment, and peak rotation moment.
Discussion: The results of this study agree with previously published data that show TKA surgery does begin to bring walking gait kinematics and kinetics post-TKA surgery toward asymptomatic values (Hatfield et al., 2011), showing improved knee joint function. Significant negative linear associations also exist between most pre-operative discrete gait metrics and their associated change scores that show subjects with more reduced gait function pre-operatively stand to gain the most benefit post-operatively, with the knee adduction moment being the metric that stands to improve the most. To date, most of the literature reports group averages for gait biomechanics metrics, whereas looking at
those subjects meeting asymptomatic values pre and post-operatively can begin to quantify TKA outcome on a patient-specific level as well as what metrics TKA tends to target for improvement. The majority of participants did not achieve gait kinematics (flexion angles and velocity) within a one standard deviation of asymptomatic adults post-operatively. The majority also continued to have high mid-stance knee adduction moments, suggestive of a lack of unloading of the medial compartment of the knee during gait, as well as lower than asymptomatic late stance knee extension moments. These particular gait mechanics are characteristic of end stage knee OA, and are not restored toward asymptomatic levels in the majority of individuals after total knee arthroplasty surgery.

**Significance:** The implications of these results are that pre-operative joint functional state is a major contributing factor in post-operative joint function, and the percentage of individuals treated with TKA whose gait mechanics move toward asymptomatic levels varies depending on the metric. Therefore, the pre-surgical dynamic state of the joint should be an important consideration for surgical decision-making aimed at improving the functional state of the joint, and the variable biomechanical response of individuals to TKA treatment should be a consideration for future research.

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