Gait Dynamics for Level and Inclined Surfaces: A Comparison Between TKA Patients and Healthy Controls

Sarah Reynolds, MSc¹, Mario Lamontagne, PhD², Geoffrey Dervin, MD, FRCS¹.
¹University of Ottawa, Ottawa, ON, Canada, ²Univrsity of Ottawa, Ottawa, ON, Canada.

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Introduction: Total knee arthroplasty (TKA) has been shown to significantly improve gait dynamics for individuals suffering from severe osteoarthritis(1). However, previous research has limited gait analysis for TKA patients to level surfaces. Gait analysis among young, healthy individuals has shown that lower limb mechanics change as individuals move from level to inclined walking surfaces, with the most pronounced changes occurring at the knee joint (2,3). These changes should be kept in mind when determining functional outcomes for TKA patients with respect to gait analysis. The purpose of this study was to compare gait patterns between TKA patients and controls during both level and inclined tasks.

Methods: Sixteen participants (12 M/4 F; age=62±6, BMI=30±3 kg/m²) were recruited from the local hospital for the TKA participant group. Inclusion criteria dictated that participants be between 50-75 years of age, with a BMI ≤35 kg/m², having undergone unilateral TKA for severe knee osteoarthritis within the past 6-12 months (mean=11±5 months). Control participants (n=16; 12M/4 F; age=63±8, BMI=27±4 kg/m²) were recruited from the local community with similar inclusion criteria, having no lower limb injuries or musculoskeletal diseases. Three-dimensional motion analysis was conducted using 10 Vicon MX cameras; inclined walking trials were performed on a 4 metre ramp set at a 9° (12.5%) incline. Ground reaction forces were calculated using 2 force plates embedded within the respective walkway; kinetic measures were calculated using an inverse dynamics approach. Participant performed 5 trials for each walking task. Individual averages across these trials were calculated for each participant and were later used to calculate group means for each variable of interest. Trials were analyzed and time normalized (for consecutive heel strikes) in a customized Matlab software; statistical analysis was conducted using SPSS 21.0 software. One-way ANOVAs were conducted to compare peak kinematic and kinetic values across walking tasks (Level, Uphill, Downhill) and groups (TKA vs. Control), with an α=0.05.

Results: For each of the walking tasks, TKA participants exhibited significantly reduced knee flexion angles in both the early stance (10-30%) and swing (62-100%) of the gait cycle (Table 1), along with reduced power absorption and generation at the knee throughout the gait cycle (Figure 1). It is of interest to note that no significant differences were observed for hip kinematics or kinetics between the TKA and control groups during any of the three walking tasks.

During each of the gait tasks TKA patients experienced reduced extension moments during early stance; however this only reached statistical significance during level (p=0.049) and downhill (p=0.01) walking. In contrast, uphill walking produced significantly different peak knee extension moments (p=0.018) between the TKA and control groups in late stance/pre-swing (40-60% of gait cycle), as TKA participants exhibited peak extension moments of 0.1±0.08 N*m/kg, compared to controls (mean=0.4±0.4 N*m/kg).

It is of interest to note that despite these aforementioned differences between the TKA and control groups, all of the participants exhibited similar adaptations to their gait patterns when adjusting between level and inclined walking. This includes increased hip and knee flexion angles and extension moments, as well as significantly greater power generation at the hip. During downhill walking, both groups experienced reduced flexion angles and extension moments at the hip, while the knee had significantly greater flexion angles and extension moments, allowing for greater power absorption, compared to level walking.

Discussion: Consistent differences in knee power and flexion angles throughout both level and inclined walking tasks suggests that these discrepancies may be part of an adapted gait pattern that patients have developed, either as a continuation of pre-operative gait patterns or due to post-operative outcomes (i.e. pain, reduced muscle activation, flexion contractures). Due to the more demanding nature of inclined walking tasks, it was anticipated that a greater number of discrepancies would be observed between TKA and control groups during these tasks, compared to level walking; however, this was not the case. Overall, level walking produced the greatest differences between the groups, with discrepancies in knee flexion/extension angles and moments, as well as reduced peak power generation and absorption at the knee throughout the gait cycle. It is possible that inclined gait tasks had fewer differences between the groups because the more demanding nature of the task reduced variability or required greater muscle activation, which may have compensated for other differences in gait mechanics (such as those observed in level walking). This information warrants further research to examine the role of muscle activation and strength during these dynamic tasks, and how they impact gait patterns during level and inclined walking. The similar adaptations among both groups between level and inclined walking tasks suggests that TKA patients maintain similar movement patterns to healthy controls; however, they are unable to reach similar peak values throughout the movement, compared to their healthy counterparts.

Significance: This study is the first to our knowledge that has examined gait dynamics for TKA patients on an inclined walking surface. Our findings show that some parameters, such as reduced knee flexion angles, persist during both level and inclined gait, and therefore may be a characteristic of post-TKA gait mechanics. As level walking produced greater differences between
TKA and control groups than the inclined walking tasks, it is important to consider the role of muscle activation when comparing level and inclined walking tasks - future research is warranted for this topic.

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</table>

Table 1: Joint kinematic and performance during level and inclined walking tasks.

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Figure 1. Knee power measured throughout the gait cycle for level and inclined walking tasks. Grey area represents normative range calculated as one standard deviation above and below the mean for the control group.