

# Knee Joint Biomechanics of Total Knee Arthroplasty Patients During Daily Activities

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**INTRODUCTION:** Total knee arthroplasty (TKA) is a prevalent orthopedic surgery in the United States, primarily employed to address end-stage knee osteoarthritis (OA) [1]. A majority of TKA recipients report enhanced functionality [2], pain alleviation [3], and satisfaction with surgical results [4]. Beyond pain relief, the enhanced capability to undertake daily tasks is crucial for TKA patients, as it profoundly affects their quality of life. Among these tasks, stair ambulation demands higher knee flexibility and coordination of the lower extremities [5]. Studies indicate that post-op patients exhibit notable deficits in the frontal plane moment and sagittal plane angle during stair navigation compared to healthy individuals. Given the intricate nature of biomechanical variables, clinicians often find it difficult to attain a thorough understanding and make informed judgements. To counter this, we introduced a streamlined integrated measure, the knee biomechanics index (KBI). This index, rooted in biomechanical parameters relative to healthy controls, serves as our primary metric for investigating longitudinal disparities and cross-activity comparisons. The objective of this research is to evaluate KBI enhancements among TKA patients across different daily routines. We hypothesized that: 1) no significant KBI advancements occur in all daily tasks post-op, and 2) no discernible variations exist in the KBI of TKA patients when comparing different daily activities.

**METHODS:** A total of 20 participants who underwent unilateral posterior-stabilized TKA using the Persona implant (11 males, 9 females; age: 65±6 years, BMI: 31±5 kg/m<sup>2</sup>) and another 20 participants who underwent bi-cruciate stabilized TKA via the Journey II implant (11 males, 9 females; age: 65±6 years, BMI: 31±4 kg/m<sup>2</sup>) were recruited. These participants were evaluated both pre-operation (pre-op) and at the 6-month post-operation (post-op). Additionally, a control group comprising 20 individuals (11 males, 9 females; age: 63±6 years, BMI: 28±5 kg/m<sup>2</sup>) was also examined. The study was endorsed by an institutional research board, and every participant provided written informed consent. All subjects participated in various activities: level walking, ramp ascent, ramp descent, stair ascent, and stair descent. Motion data during these activities were captured using a 10-camera VICON system (Oxford, UK) at 120 Hz. Two force plates (AMTI) were used to record ground reaction force at 1200 Hz. For accurate motion tracking, 52 reflective markers were affixed bilaterally to each participant. A custom-developed and validated MATLAB program was used to perform the analysis. To better understand the differences in biomechanics during five distinct daily activities, KBI was developed based on knee kinetics, kinematics and gait parameters. Knee kinematics were analyzed across three different planes of motion: sagittal, frontal, and transverse. Knee kinetics were analyzed in three different planes as well, including flexion/extension moment, adduction/abduction moment, internal/external moment and knee contact force during the gait cycle. The weight of each variable was determined based on its contribution to functional improvements, participants with values within one standard deviation of the mean received full points when compared to the healthy controls. In contrast, those within two standard deviations received half points. Participants with values outside of two standard deviations or those who failed to perform a specific motor task received zero points, with a maximum achievable score of ten. The KBI scores for pre-op and post-op groups were determined based on their proximity to the control group. To discern differences in daily activities, a repeated measures ANOVA, considering both groups (pre-op vs. post-op) and tasks (five daily activities), was performed.

**RESULTS:** A significant group×task interaction was observed in KBI ( $p<0.01$ , Table 1 and Fig. 1). A significant group main effect was also found in KBI, indicating that KBI for five daily activities significantly increased at follow-up. Post hoc analysis revealed that KBI of level walking was significantly higher than those of stair ascent and stair descent. There were no significant differences in KBIs among level walking and ramp ascent or ramp descent. The ramp ascent KBI was still significantly higher than those of stair ascent and stair descent. In terms of improvements in KBI, the enhancements in daily activities decreased as the difficulty of daily activity increased, with the improvements in KBI of level walking being significantly greater than those of stair ascent and stair descent, respectively.

**DISCUSSION:** Both hypotheses were rejected. The KBI showed improvements during TKA follow-up, and the KBI for stair ascent and stair descent were significantly lower than that for ramp ascent, ramp descent, and level walking. This KBI data suggests that TKA patients performing stair ambulation need superior functional capacities. Given that the KBI was derived from seven principal biomechanical variables and weighted based on their significance, no marked difference was observed between level walking and inclined walking in the KBI. Another plausible rationale for this result might be the unvaried degree and length of the ramp [6]. From the observed improvements in the KBI (Fig 1), we noted that the enhancement in the KBI during level walking was substantially more pronounced than during stair ascent and descent. This further implies that TKA patients haven't fully regained functional performance in high-demand activities. This research could offer a biomechanical benchmark to help clinicians assess the recovery level of TKA patients. Furthermore, it has the potential to guide therapists in crafting effective rehabilitation strategies for those recuperating from TKA.

**REFERENCES:** [1] Feng, J.E., et al., J Multidiscip Healthc, 2018. [2] Moffet, H., et al., Arch Phys Med Rehabil, 2004. [3] Jones, G., et al., Arthritis Rheum, 2000. [4] Ethgen, O., et al., J Bone Joint Surg Am, 2004. [5] Valenzuela, K.A., et al., Clin Biomech (Bristol, Avon), 2019. [6] Wen, C., et al., J Biomech, 2019.

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Table 1: Knee biomechanics index (KBI) (mean ± std) for patients during daily activities. (\* significant group main effect, ^ significant interaction group× task interaction, <sup>c</sup> significant difference between level walking and stair ascent, <sup>d</sup> significant difference between level walking and stair descent, <sup>f</sup> significant difference between ramp ascent and stair descent, <sup>g</sup> significant difference between ramp ascent and stair descent, <sup>i</sup> significant difference between ramp descent and stair descent)

KBI*^	Pre-op	Post-op
Level Walkng <sup>cd</sup>	5.51±0.41	7.92±0.57
Ramp Ascent <sup>fg</sup>	5.58±0.39	7.64±0.64
Ramp Descent <sup>i</sup>	5.63±0.37	7.48±0.5
Stair Ascent	4.59±1.3	6.05±1.25
Stair Descent	4.25±1.44	5.75±1.55

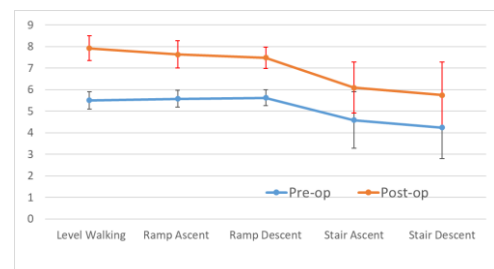


Fig. 1: Knee biomechanical index in five daily activities prior (Pre-op) and 6-month post (Post-op) TKA surgery