Intact Leg Loading in Simulated Unilateral Transfemoral Amputee Gait

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Introduction: Individuals with unilateral transfemoral amputation (TFA) are exposed to a higher risk of developing knee osteoarthritis (OA) in their intact leg[1]. Their altered gait patterns could lead to increased mechanical loads on the intact knee[2], which is considered as a risk factor of knee joint injuries including OA. Previous studies have examined peak knee adduction moment (KAM) and peak vertical ground reaction force (vGRF) rate as the surrogates for the knee joint loading in individuals with and without unilateral TFA[2,3]. However, some characteristic differences between the two groups (with and without TFA) might have been masked in the comparisons because physical and biomechanical variabilities among amputee population are generally high and difficult to control. In fact, studies have shown different results of peak KAM between individuals with and without TFA[2,3]. The purpose of this study was to examine whether the intact knee joint loading in subjects who "simulate" TFA gait differs from the loading in the same subjects performing normal gait.

Materials and Methods: A custom TFA-gait simulator was fabricated using iWALK2.0 (iWALKFree, Inc. Long Beach, CA) and a set of a prosthetic knee, pylon and foot (LIMBox, LIMBS International, Inc., El Paso, TX) to firmly attach to the thigh and shank (Figure 1). Five healthy non-amputated subjects (20.8 ± 1.6 yrs., 69.8 ± 8.2 kg) participated in the study with consent to the protocols approved by the University's institutional review board. The subjects were acclimated to the TFA simulator until they were able to perform steady walking at or faster than their 70% of self-selected walking speed (SSWS). Three types of gaits were performed across a six-meter walkway in a random order: normal gait at 100±5% SSWS; slow gait at 70±5% SSWS; and simulated TFA gait at 70±5% SSWS. Gait speeds were monitored using infrared timing gates. Kinematic and GRF data were acquired using a motion capture system (T10, VICON, Oxford, UK) and two force plates (FP4060, Bertec Corp. Columbus, OH), sampled at 100 and 1000 Hz, respectively. The data were then low-pass filtered using 4th-order zero-lag Butterworth filters at 6 and 50 Hz, respectively. Custom MATLAB script (r2015b, MathWorks Inc., Natick, MA) was used to compute the KAM of the intact leg, expressed in the shank coordinate system. The peak KAM and peak vGRF rate during early stance in the three gaits were obtained and evaluated using one-way repeated measures ANOVAs with Tukey's post-hoc analysis (Minitab 18.1, Minitab Inc., State College, PA).

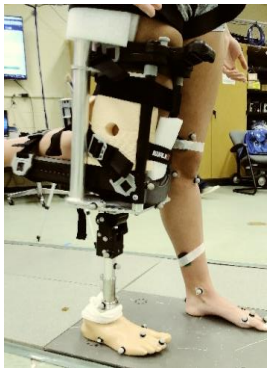

Figure 1. Fabricated TFA simulator attached to the right leg

Results and Discussion: The peak KAM and vGRF rate in TFA gait were significantly higher than those in slow gait (Figure 2A, B, p=0.042 and 0.011, respectively). The peak vGRF rate in TFA gait was also higher than that in normal gait (Figure 2B, p=0.027). Previous studies examining the knee joint loading in the intact leg have shown conflicting results of peak KAM[2,3]. The discrepancy among studies may be due to the variability in their amputee subjects. Using TFA simulator enables the comparisons to the normal baseline performance in the same subjects, which may highlight some characteristic differences in TFA gait.

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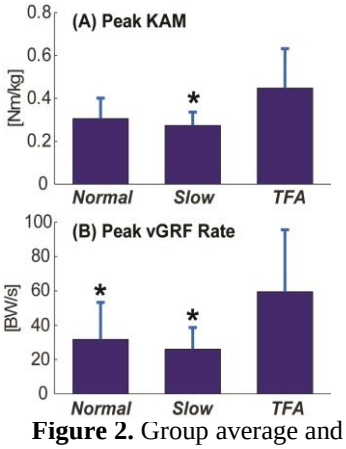

Figure 2. Group average and standard deviation of (A) Peak KAM and (B) peak vGRE rate during three different gaits. The * marks indicate significantly *lower* loads than the TFA condition.

Conclusions: The present study showed that simulated unilateral TFA gait could impose high mechanical loads on the intact knee. Our previous pilot study has shown comparable gait biomechanics between actual and simulated TFA gaits[4]. Therefore, simulating TFA may be useful for designing and evaluating new prosthetic devices for unilateral transfemoral amputees to reduce excessive intact-leg loading.

References: [1] Struyf PA et al., *Arch Phys Med Rehabil*. 2009; 90:440-6. [2] Miller RH et al., *PeerJ*. 2017; DOI 10.7717/peerj.2960. [3] Pruziner AL et al., *Clin Orthop Relat Res*. 2014; 472:3068-75. [4] Henson D. et al., *Annual Meeting of the American Society of Biomechanics*. 2017.