Defining Loading on Lower Limb Joints with Partial-Weight Bearing Crutch Ambulation: A Biomechanical Study.

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Introduction

The main concept of a crutch is to off-load a desired joint from the detrimental forces of ambulation when another limb cannot bare weight. In this study we looked at forces and moments acting on ankle, knee, and hip joints with a swing-through gait in a partial-weight bearing manner and compared the results across three crutch designs (axillary, lofstrand, and platform). The authors hypothesized that the healthy limb in partial-weight bearing ambulation endures significantly higher forces and moments across all joints when compared to the injured one. Also there will be higher forces and moments in the injured leg when using a platform crutch when compared to the axillary and lofstrand crutches.

Methods

A total of ten healthy subjects (5 females, 5 males) participated in the study after obtaining approval by the Internal Review Board (IRB). Subjects were instructed on proper use of the crutches by a study personnel and given time to practice putting 50 lbs. (22.7 Kg) on their simulated injured leg. After they were able to reproduce it three times in a row, they along with the investigators were blinded to the weight exerted on the simulated injured leg during the experiment. A motion capture system (Vicon®, Oxford, UK) was calibrated and used to track their movement. Utilizing thirty nine stereotactic markers mounted on the skin; subjects walked over four Kistler® force plates (Kistley Instrumente AGm Winterthurm, Switzerland) in a partial-weight bearing swing-through gait with each of the crutch designs. The external loads and moments acting on joints in the axial, sagittal, and coronal planes (Fx, Fy, Fz and Mx, My, Mz) were calculated for both the full and the partial weight bearing legs. Vectors in 3 planes were combined so only peak resultant joint forces resolved from the external load vectors on each joint were reported. All force and moment values were normalized for body weight (Newton of joint force/Kg of body weight, Newton millimeter/Kg of body weight).
An ANOVA multifactorial comparison with Bonferroni correction was performed to compare peak force and moment values on one joint with all crutch designs, and a Students t-test was performed to look at the one joint bilaterally with each crutch design separately.

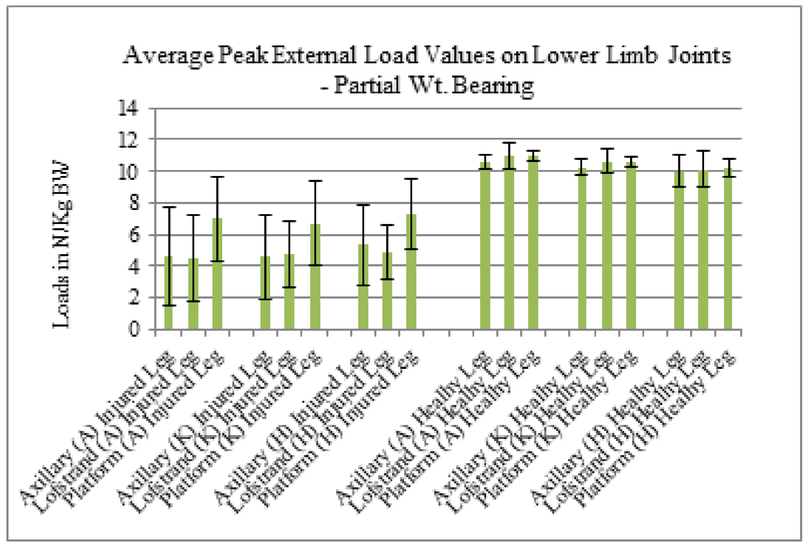

Figure 1: Average combined peak force values on lower limb joints (ankle-A, knee-K, and hip-H) in swing-through partial-weight bearing gait.

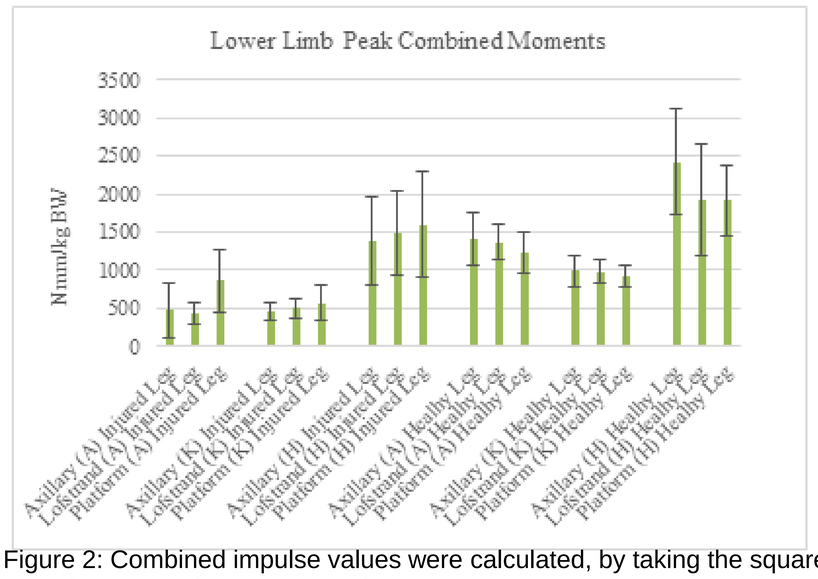

Figure 2: Combined impulse values were calculated, by taking the square root of the sum of the squares of the three planes, and reported above. Swing-through gait shows high impulses combined impulse on the ankle joint.

Significance

This study provides insight into partial-weight bearing mechanics of the lower limbs to further guide health professionals towards the best fit for their trauma patients.

Results

The full weight bearing leg endured significantly higher forces when compared the partial-weight bearing one across all three crutches in all joints ($p<0.001$). The injured leg showed no significant differences when compared across all crutches in all joints, except for the hip joint where it endured significantly higher forces in the platform crutch when compared to the lofstrand design ($p=0.036$). For the moments, the full weight bearing limb endured significantly higher moments than the partial-weight bearing one across all crutches in all joints ($p<0.001$), except for the hip joint in the platform and lofstrand crutch where differences were not statistically significant. In the injured leg significant results were only found in the ankle joint with using a platform crutch, which yielded higher moments than the other two designs ($p\leq0.005$).

Discussion

Partial weight bearing ambulation is prescribed to “ideally” exert a controlled amount of weight on the injured leg and have its healthy counterpart carry the most of the body weight. This study looked at ten otherwise healthy subjects and tested their ability to lift enough weight off their simulated injured leg to cause significantly low forces and moments exerted on their simulated injured limb. The hypothesis was true for force and mostly true for moments. The moments exerted on the hip joint by the platform and lofstrand crutches were not significantly different between the two limbs. To further investigate the best suitable crutch for trauma patients, this study looked the behavior of the injured limb across the three tested crutches. The hip joint endured higher forces in the platform crutch compared to the lofstrand, and the ankle joint endured higher moments using the platform crutch when compared to the other two designs. Therefore, this study concludes that, from a biomechanical stand point, the axillary crutch is the best choice for lower limb joints in a swing-through partial-weight bearing gait. The platform crutch showed larger mechanical loads on the subjects, but its use in polytrauma patients is of a necessity. Caution should be used when interpreting the data to a clinical scenario, as the testing was done on healthy young subjects and the body biomechanics can be different in a trauma patient. Also, upper limb mechanics were not reported in this contribution and will be object of a future study.