The Effects of Simulated Knee Arthrodesis and Temporal Acclimation on Gait Kinematics

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Disclosures: 
E.M. Lucas: None. R. Hutchison: None. J. Marro: None. T. Gambon: None. J.D. DesJardins: 3B; DJO Surgical. 5; ArthoSurface, DJO Surgical. 6; ArthoSurface, DJO Surgical, Smith & Nephew.

Introduction: Knee arthrodesis, or fusion, is an end stage orthopaedic procedure that is performed to treat chronic pain and instability in cases of multiple failed knee replacement, bone loss, traumatic injury, or loss of the quadriceps extensor mechanism[1], [2]. Arthrodesis can enable a patient to walk, though studies investigating the resulting changes to gait biomechanics have been limited. Knee arthrodesis is performed in a select number of cases and for a diverse range of etiologies, making patient gait studies in this area difficult. Previous studies have simulated knee arthrodesis in healthy subjects by applying an immobilizing brace or cast. These studies have not, however, studied gait adaptation resulting from long-term knee immobilization, as would be the case in clinical arthrodesis (See Table 1) [3]-[11], leaving significant uncertainty regarding how chronic knee immobilization affects gait kinematics.

<table>
<thead>
<tr>
<th>Study</th>
<th>Acclimation Method</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hanada and Kerrigan[3]</td>
<td>Walk on treadmill until steady-state heart rate</td>
<td>No time given</td>
</tr>
<tr>
<td>Abdulhadi et al.[4]</td>
<td>Walk down 20ft. data collection area at least 5x until steady-state heart rate</td>
<td>Approx. 3 min</td>
</tr>
<tr>
<td>Mattson and Brostrom[5]</td>
<td>Walk until steady-state heart rate</td>
<td>&gt;4 min</td>
</tr>
<tr>
<td>Lewek et al.[6]</td>
<td>Walk on treadmill until “metabolic” “steady-state”</td>
<td>5 min</td>
</tr>
<tr>
<td>Kerrigan et al.[7]</td>
<td>Walk until steady-state oxygen consumption</td>
<td></td>
</tr>
<tr>
<td>Senden et al.[8]</td>
<td>Familiarize with limitation</td>
<td>Approx. 1 min</td>
</tr>
<tr>
<td>Boone[9]</td>
<td>“The subjects were previously familiarized with the treadmill.”</td>
<td>10 min</td>
</tr>
<tr>
<td>Kerrigan et al.[10]</td>
<td>“To allow some accommodation time, each subject walked up and down the length of the walkway approximately five times before data was collected.”</td>
<td>No time given</td>
</tr>
<tr>
<td>Waters et al.[11]</td>
<td>“The subjects were instructed to become accustomed to walking”</td>
<td>No time given</td>
</tr>
</tbody>
</table>

The primary objective of this research is to quantify the kinematic changes to gait induced by simulated knee arthrodesis during both acute and chronic (+24 hours) conditions. We hypothesize that gait kinematics continue to change as subjects acclimate to an immobilized knee.

Methods: This study received Institutional Review Board approval from all partner institutions. A gait lab equipped with an 8-
camera motion capture system (Qualisys, Gothenburg, Sweden) and a 6-axis force platform (AMTI, Newton, Massachusetts) was used for this study. Motion and force data was processed using Visual3D (C-Motion, Germantown, Maryland), and the method of Grood and Suntay was used to describe joint rotation [12].

Ten subjects (age range 18-30 years; 5 males, 5 females) with no history of gait abnormalities were recruited for this study. Subject height, mass, and Dual Xray Absorptiometry (DXA) derived estimates of mass and tissue composition for each body segment were obtained. Reflective markers were placed on each subject over known anatomic landmarks. Subjects were then instructed to walk along an 8-meter pathway a minimum of ten times for control gait data. Knee arthrodesis was then simulated in each subject using a locking knee brace (DJO Global, Vista, California). Experimental trials commenced immediately following fitting of the brace, preventing the subjects from gaining any familiarity to walking with an immobilized knee. Upon completion of ten trials, subjects were then guided to a treadmill, where they walked with the brace for 0.25 miles. Upon completion, another ten experimental trials were captured. Subjects then walked on the treadmill with the brace for an additional 0.50 miles. Upon completion, another ten experimental trials were captured. Subjects were then sent home for the day with the brace and instructed to wear it for the next 24 hours. The next day, another ten experimental trials were captured.

**Results:** Consistent, statistically significant changes to gait were observed across subjects when the knee was immobilized. Increased pelvic rotation was observed leading up to contralateral heel strike. Pelvic obliquity was increased at contralateral toe off, and reduced at ipsilateral toe off through heel strike. Pelvic tilt was reduced beginning at contralateral heel strike, and reached its lowest point at mid-swing. There was a delay in the initiation of hip flexion on the ipsilateral side, as well as reduced hip adduction at midstance and ipsilateral toe off. The joint angle of the knee remained relatively static in all rotation planes. There was a dramatic decrease in plantarflexion at ipsilateral toe off which was immediately followed by a greater degree of

![Figure 1: Fitted Knee Brace](image-url)

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dorsiflexion (Figure 2). Onset of hip flexion velocity was delayed, and there was no extension velocity peak prior to ipsilateral heel strike. There was shift in hip adduction/abduction peaks to earlier in the gait cycle. Knee joint velocities remained approximately zero at all phases of the gait cycle. There was a reduction in ipsilateral plantarflexion velocity, and a shift in the plantarflexion and dorsiflexion velocity peaks at toe-off.

**Discussion:** Subjects adopted interrelated gait compensations to account for knee immobilization. With the knee unable to ‘break,’ or flex, towards the end of stance phase, pelvic rotation towards the trailing limb increased and hip extension continued through toe off. We observed a corresponding decrease in plantarflexion at this point. A constrained knee also increases the effective length of the limb during swing phase, requiring compensations to assist in ground clearance. This is observable as increased pelvic obliquity, a delayed onset of hip extension, and a rapid and sustained increase in ankle dorsiflexion immediately following ipsilateral toe off. Prominent trends associated with acclimation to knee immobilization were not observed.

**Significance:** Based on the limitations of the studies cited below, this study provides support for using normal, healthy subjects fitted with an immobilizing brace as appropriate surrogates for people with long-term knee immobilization. Furthermore, while changes to gait biomechanics have been observed as a result of knee immobilization, they have not been quantified before now - publication of this data could support further research investigating the link between knee arthrodesis and osteoarthritis of other joints.

**Acknowledgments:** The authors would like to acknowledge Ray Moss for his generous help, as well as DonJoy Global for providing the knee brace.

**References:**


ORS 2014 Annual Meeting
Poster No: 1679