Measuring transtibial prosthetic socket-to-residuum interface coupling in gait using 3D motion capture

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Abstract

Introduction: Fit and function of a prosthetic socket are often reported as the main reason for dissatisfaction within lower-limb amputees [1, 2], leading to further reductions in mobility. One way of measuring the performance of a prosthetic socket is through analysing the socket-to-residuum interface coupling, which describes how the prosthesis changes in pose relative to the residuum. Although motion capture currently measures fewer degrees of freedom (DOF) than X-rays, it is predominantly used due to its reduced risk to participants and its ability to analyse dynamic tasks. However, some recent methodologies proposed still require bespoke prosthetic sockets to allow visibility of reflective markers placed on the liner or residuum [3, 4]. Tang, et al [5] removed this requirement by calculating three of DOF of movement of a virtual residuum for a transfemoral amputee.

Research Question: Can 3D motion capture be used to increase the number DOF of coupling measured during walking gait for transtibial amputees?

Methods: Lower limb kinematics and kinetics were captured for a single unilateral transtibial amputee. Twenty-two reflective markers were placed bilaterally on the anterior and posterior superior iliac spines, greater trochanters, medial and lateral femoral condyles. The sound limb had markers placed on the medial and lateral malleoli; first, second, and fifth metatarsals; and calcaneus. The prosthesis had medial and lateral ankle pivot markers, and four matching foot markers. Four marker clusters were also placed on the thighs, shank of the sound limb, and prosthesis socket. Ten walking trials, a total of 15 strides, were captured using 13 Qualisys cameras. As the prosthesis used supracondylar suspension which obscured the femoral condyles two static trials, with and without the prosthesis donned, were required. Data were exported to Visual3D for joint based analysis and the marker locations was exported to MATLAB for coupling calculations.

Results: It was possible to measure five of the six DOF of coupling throughout the gait cycle (Figure 1). The ranges of movement were similar to other coupling investigations.

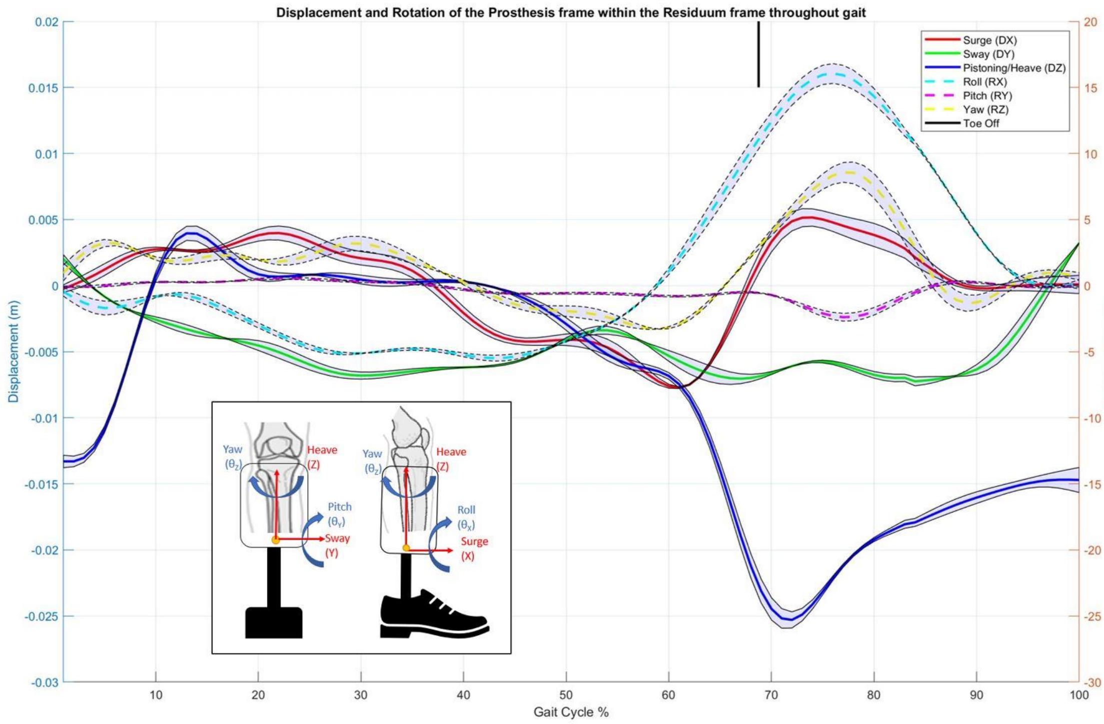

Figure 1: Mean measures of displacement and rotation of the prosthesis relative to the residuum throughout the gait cycle.

Discussion: For transtibial amputees, using the same markers as those used in traditional gait analysis, but with an additional doffed static calibration allowed five of the six DOF of coupling to be measured (Figure 1). The one DOF that could not be measured was the pitch of the prosthesis, rotation about the knee axis. This is due to the residuum frame using the ankle location markers in its calculation. Surge movement of the prosthesis (lateral displacement in the sagittal plane) will create a false result of rotation about the knee axis due to the small rotation of the residuum frame, which can be seen occurring just after toe-off in Figure 1. These results demonstrate the viability of this method.

References:

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