INTRODUCTION
Historically, lower limb prostheses include passive mechanical units at both the knee and ankle. Technological advancements have resulted in powered prostheses with actuated motors to position lower limb prosthetic joints and provide positive power. Currently, these components are being controlled by the information measured from various electro-mechanical sensors in the prosthesis. Supplementing this information with input from the user via electromyographic (EMG) data may enhance the intrinsic control information provided to powered prosthetic components. In order to extract useful control information, it is imperative that consistent and high-quality EMG data be collected from the individual’s residual limb each time they don the socket. The authors have utilized several approaches to maintain consistent electrode placements and contact on individuals with transfemoral and transtibial amputations during static, non-weight bearing conditions, and during dynamic weight-bearing activities.

METHOD
Northwestern University IRB approved studies focused on fitting powered lower limb prostheses have occurred at the Rehabilitation Institute of Chicago over the past several years. These various experimental protocols have necessitated the use of robust EMG control systems that rely on either: differentiation of signals between antagonistic muscle sites, or via pattern recognition algorithms.

Subjects: 17 (3 Female and 14 Male) individuals with transfemoral amputation and 8 (2 Female and 6 Male) with transtibial amputation levels were included. Etiology of amputations varied from trauma to tumor.

 Procedures: For the static, non-weight bearing condition, individuals have been fit with self-adhesive electrodes on the skin of their residual limb which can be attached to wire leads. Myoelectric control is demonstrated in a virtual environment, as well as with active lower limb prostheses.

During dynamic activities, such as walking, negotiating ramps, and climbing stairs, two strategies have been used concurrently to collect EMG inside prosthetic sockets: 1) Elastomeric gel liners with embedded fabric electrodes and conductive leads and 2) Electrode domes mounted within the thermoplastic socket interfaces with integrated low-profile leads and electronics. These socket-based EMG systems are used to control powered prosthetic components, including prototypes of the iWalk Biom™ ankle (for transtibial users) and the powered knee-ankle unit (for transfemoral users).

Subjects performed numerous dynamic activities (walking, ramps, stairs) within laboratory environments while wearing the EMG data collection sockets. Control of the powered prosthesis was compared before and after adding EMG data to supplement information from the electromechanical sensors in the prosthesis.

RESULTS
Static conditions using self-adhesive electrodes demonstrated reliable EMG while repeatable EMG information was gathered during dynamic testing as well for formulation of a classifier-based control.

DISCUSSION
These results demonstrate that a variety of methods, similar to those used in upper limb fittings, may be used to collect high quality EMG data during a range of static and dynamic activities. The EMG data can subsequently be utilized for enhanced control of powered prosthesis when added to information collected from the electromechanical sensors.

CLINICAL APPLICATIONS
As powered lower limb prostheses continue to evolve, it is essential that the control be maximized. In order to accomplish this task, it is necessary to gather the EMG in a robust system that is both comfortable and reliable to the user. Both liners with embedded electrodes and a method for creating low-profile, socket-integrated systems should be explored so that individuals with lower limb amputations can benefit from optimal control of powered prostheses.

REFERENCES