INTRODUCTION
Individuals with lower limb amputations have utilized gel materials for comfort and suspension since the early 1980’s, and today many variants exist. Use of gel liners with upper limb prostheses has been slow to develop, although introduced in the 1990’s (Ross, 1990) (Radocy, 1995). In parallel with gel liner development, myoelectric control of upper limb prostheses has been evolving for approximately 50 years. There have been some attempts to combine gel liners and myoelectric control, but with moderate success (Salam, 1994) (Daly, 2000). With the advent of powered lower limb components, the potential of lower limb myoelectric control also needs to be explored. In order to improve upon the current status of gel liners combined with externally powered fittings, it is essential to approach the clinical challenges that arise from merging these technologies. The objective of this project was to develop a gel liner interface that could provide comfort, suspension, and maintain electrode contact in various postures, as well as provide a simple means of donning and permit the use of both traditional (direct) myoelectric control as well as pattern recognition control.

METHOD
Northwestern IRB approved studies focused on fitting powered upper limb and lower limb prostheses have occurred at the Rehabilitation Institute of Chicago over the past several years. Many of these experiments have necessitated the use of robust myoelectric control systems that rely on either: traditional direct control, where antagonistic pairs of muscles perform independent signals, or pattern recognition control algorithms that use signals from a ‘grid’ array of electrodes to classify intended movements. We began to explore alternative designs of gel liners with myoelectrically controlled upper limb prostheses during the Revolutionizing Prosthetics Projects 2007 and 2009. Initial designs incorporated the use of stainless steel domes in off-the-shelf (OTS) liners. This differed from the aforementioned work by Daly in that the interface would engage with the prosthesis without the need for the user to attach external leads, etc. The designs evolved in several manners and have resulted in the current use of conductive fabric electrodes. The fabric electrode and leads are attached to the liner fabric prior to the injection of the thermoplastic elastomer, and fed through a distal component for transmission of the signals to the electronics. Having the leads integrated between the gel and fabric of the liner, provides insulation for the conduction of signals as well as ease of use for the patient and clinician. These gel liners, with embedded electrodes, are under development by the Rehabilitation Institute of Chicago in conjunction with Alps South. Direct control liners have been created such that the electrode locations match the measured signals from the subjects, as is typically performed in traditional myoelectric fittings. “Grid-style” liners are fabricated in a similar fashion; however, the initial placement of the electrodes is not reliant on myoelectric testing. An array of three evenly spaced rings of four electrodes is arranged within the liner plus additional reference electrode. The electrode pairs are then configured electronically for use with pattern recognition control.

RESULTS
To date, the liner development has progressed to a design that has been utilized in two “home trial” studies with upper limb, myoelectric fittings and one study with subjects having transtibial amputations using a powered foot ankle system. Individuals with upper limb prostheses have partaken in outcome measures including the Box and Blocks, SHAP, Jebsen-Taylor and Clothespin Re-location and ACMC. Results of these are described in a separate presentation.

DISCUSSION
Much development has occurred, with additional refinements necessary in order to implement liner systems for myoelectric control into accepted practice. These liners have proven successful in providing EMG data for control of powered upper limb and lower limb prostheses while the development of corresponding electrical and mechanical components have continued to evolve.

CLINICAL APPLICATIONS
It is the goal of this development to provide a robust gel liner system that is applicable in both powered upper limb and lower limb fittings. Commercially available, powered, lower limb prostheses are still in their infancy. However, maximizing the benefits of the components with both intrinsic and myoelectric control may enable users to control their devices in a manner that has not previously been possible.

REFERENCES
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