INTRODUCTION
In previous studies, clinical experience and scientific evidence have reported on the benefits derived from the utilization of a reciprocating gait orthosis (RGO) in paraplegic patients (Subbarao 1991). The benefits include:

- Reduced incidence of joint contractures and pressure sores
- Prevention of osteoporosis
- Improved bowel function & urinary drainage
- Improved peripheral circulation
- Improved interaction with the environment
- Improved gait characteristics
- Improved interaction with peers

The drawbacks to RGO use are reported to be slow walking speed, high energy consumption, difficulty in donning and doffing and limited long term utilization. If not used for functional gait, the device is mainly used for therapeutic exercise (Waters 1989, Sykes 1995, Scivoletto 2000, Fatone 2006).

In a series of spinal cord injury cases, additional component options were progressively utilized to address the main drawback to RGO functional use. The technical additions address center of mass (COM) positioning, the dynamics of limb progression in swing phase and improving the self donning and doffing task.

METHOD
The type of RGO mechanism that provides efficient reciprocal hip motion has been explored (Ijzerman 1997, Winchester 1993). The direct mechanical system offered by the Isocentric design has proven to be more efficient than a cable connected system. In addition, a newer direct mechanical lever design with two pivot points provides increased ability to disperse gait forces instead of one pivot point as in the Isocentric. The Biocentric center bar linking the two pivoting control arms offers a common adjustment for alignment of the patient’s COM in relation to the hip joints. Adjustment of the sagittal position of the COM can optimize the transfer of trunk excursion into the reciprocal hip mechanism of the RGO pelvic component.

The addition of stance control (SC) orthotic knee joints that allow free knee motion in swing phase have been added to the knee ankle foot (KAFO) portion of a reciprocating gait orthosis (SC-RGO). The addition of the SC components doubled the patient’s velocity (Rasmussen 2007).

The lateral body compensation movement required for toe clearance in a RGO with drop lock KAFO segments is eliminated with the incorporation of stance control KAFO segments. Lateral movement in a static KAFO RGO impacts the need for stiffness in the orthosis (Stallard 1991). Reducing the lateral load in the KAFO segment allowed for the conservative addition of an abduction hinge to the femoral metal upright between the orthotic knee and hip joint.

The abduction hinge addressed self donning and doffing. Unlocking the abduction hinge with the orthosis placed in a sitting position on an armless chair provided enough clearance for the patient to transfer into the orthosis from a wheelchair. The patient then can lift and position each limb into the KAFO segment in preparation for standing. The previous abduction hinge component for an RGO was designed for a pediatric application to assist in catheter care and not necessarily for self donning and doffing. The pediatric model was not designed to absorb the high side loading forces required for toe clearance in an adult RGO with drop lock KAFO segments.

The last addition to the SC-RGO involved pneumatic knee extension springs as part of the stance control knee joints. The spring offers assist to the velocity of the lower limb in swing phase. In past SC and RGO combinations, progression of the lower limb was dependent on a gravity assisted pendulum swing. The pneumatic spring is compressed and stores kinetic energy when the stance phase knee is flexed at preswing. The spring biomimics the quadriceps muscle function in swing phase and aides swing velocity.

DISCUSSION
The clinical benefit of upright ambulation in a RGO has clearly been proven in multiple studies. The recent mechanical additions to the design combining linkage for reciprocal hip motion as well as free knee motion in swing phase and locking knee stability in stance phase represents the most advanced format of reciprocal gait for a paralytic patient. The addition of the pneumatic springs for swing velocity assist raises the definition of an RGO from a conservative assistive device into the realm of a dynamic exoskeletal system.

CONCLUSION
The clinical experience gained in this case series has offered observational evidence on the patient’s ability to physically manipulate the added SC-RGO features. The exploration was conducted within the confines of present reimbursed clinical services. The components, with the exception of the abduction hinge, were all commercially available.

The technical additions directly address the three major patient utilization barriers; energy expenditure, COM compensation, and donning and doffing. Addressing these barriers with technical improvements to the SC-RGO demonstrated improvement in use in this limited case series and will hopefully serve as a orthotic specification model for those institutions that have the capacity to scientifically measure the improved outcome.