LOWER BODY POSITIVE PRESSURE FACILITATES REHABILITATION FOLLOWING ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

INTRODUCTION
Rehabilitation after lower extremity injury or orthopaedic surgery frequently requires limited weight-bearing in order to protect healing tissues. Full weight-bearing by the patient may also be limited due to their pain and/or perceived instability. For example, anterior cruciate ligament reconstruction (ACLR) with patellar tendon autograft causes significant postoperative discomfort and knee effusions that limit unassisted ambulation for several weeks.

Lower body positive pressure (LBPP) is a new technique that reduces the loads on the lower extremities during ambulation. We hypothesized that LBPP exercise facilitates gait recovery and decreases pain associated with ambulation after anterior cruciate ligament surgery. Our goal was to evaluate safety, comfort, and gait mechanics in this fully weight-bearing postoperative population before progressing to a prospective, longitudinal, randomized trial to fully evaluate LBPP exercise as an orthopaedic rehabilitation modality.

METHODS
The LBPP technique consists of a treadmill enclosed within a pressure chamber (Fig. 1). Patients exercise on the treadmill after being sealed in the chamber at the waist using a kayak-type neoprene skirt. Positive pressure within the LBPP chamber creates a force that unloads the patient and reduces bodyweight by a factor proportional to the pressure differential (ΔP) multiplied by the cross-sectional area of the seal (A sc):

\[ \text{Bodyweight减轻量} = \Delta P \times A_{sc} \]

Six patients who underwent ACLR were exercised in the LBPP chamber before surgery and weekly for six weeks postoperatively. At each visit, the subjects walked for 5 minutes at 2.0 mph (0.89 m/s) under three load conditions (100%, 60%, and 20% of the subject’s bodyweight) in random order.

Bilateral vertical ground reaction forces (GRF), surface electromyography (EMG) of the vastus medialis obliquus (VMO) and biceps femoris (BF), and dynamic knee angle data were collected to evaluate gait mechanics. EMG signals were full-wave rectified and linear enveloped using a 50 msec root-mean-square moving average. Gait cycles were separated using the heel strike from the GRF as a trigger and time normalized to 100% progression and averaged together (12-17 cycles). EMG signals were normalized to the peak amplitude observed at 100% bodyweight (BW). The magnitude and timing of peak amplitudes were compared between conditions. Peak GRF and dynamic knee range of motion (ROM) were calculated from the continuously digitized output of the force pads and electrogoniometers. Subjects rated pain during each condition using a 10 point visual-analog scale.

RESULTS
Exercise within the LBPP chamber was possible for all patients studied. It is important to note that they were otherwise unable to ambulate within two weeks of surgery. Pain relief was significant with increased LBPP (Fig. 2). GRF was reduced significantly under LBPP conditions (p < 0.05). Peak EMG activity of the VMO and BF occurred at similar points in the gait cycle when compared to normal BW. At postoperative week one, average dynamic (ambulatory) postoperative knee ROM was 21 ± 3° with 20% BW.

Figure 2. At postoperative week one there was a significant decrease (p < 0.05) in pain during ambulation at 60% and 20% of BW as compared to the 100% (or full BW) condition.

In the early postoperative period (weeks 1-2), LBPP allowed earlier return to ambulation. During postoperative weeks three and four, LBPP facilitated greater dynamic ROM in the postoperative knee than that obtained under normal BW conditions. By weeks five and six, dynamic knee ROM was similar under LBPP and normal conditions (Fig. 3).

DISCUSSION
LBPP was well tolerated in our patients and facilitated earlier and more comfortable ambulation. Patients were able to attain clinically significant knee ROM during postoperative LBPP exercise. By markedly reducing ground reaction forces and maintaining relatively normal gait mechanics, LBPP should facilitate physical rehabilitation in clinical conditions that require decreased lower-extremity loading. Lower body positive pressure has strong potential as a rehabilitation tool in a range of conditions that require decreased lower-extremity loading. It is important to note that they were otherwise unable to ambulate within two weeks of surgery.

In summary, LBPP facilitates gait recovery and reduces pain associated with ambulation after anterior cruciate ligament surgery. LBPP exercise is well tolerated and can be used as a rehabilitation tool in clinical conditions that require decreased lower-extremity loading.

Supported by Bristol Myers Orthopaedic Research and Education Foundation Center of Excellence grant and by the UCSD Chancellors Associates.