**INTRODUCTION:**
During post-surgical rehabilitation, treadmill walking with body weight support is widely used to reduce weight bearing on lower extremities. Body unloading is achieved by many devices, including a waist-high chamber with increased pressure inside, called Lower Body Positive Pressure (LBPP) chamber, or a harness system (a standard system for unloading the lower body). The objectives of our study are to: 1) analyze the walking pattern within both devices by systematically varying body loading and dimensionless speed (referred to as Froude number $Fr^{[1,2]}$), and 2) compare LBPP walking and harness walking. By using Froude numbers, absolute treadmill speed is determined by the amount of unloading at each body weight condition, which thereby reflects dynamically similar motions. Walking in a pool was not included due to water drag on the body and because of post-surgical infection risk.

**METHODS:**
The LBPP chamber$^{[2]}$ and a harness (LiteGait) system were utilized to unweight 12 healthy volunteers (6 females and 6 males) aged 28±3 years with body mass index of 23.9±4.0 (means and standard deviations) (Figure 1). All subjects were thoroughly informed and signed a consent form approved by our IRB. Subjects walked at three body weight (BW) conditions (100%, 66%, and 33% BW) and three Froude numbers (Table 1). The Froude number$^{[2]}$ can be referred to as a dimensionless speed quantitatively considering loading $(g)$ and the subject’s leg length $(l)$ to determine the treadmill speed $(v)$ in the following equation:

$$Fr = \frac{v^2}{g \cdot l}$$

Froude numbers were chosen to investigate slow walking ($Fr = 0.09$), comfortable walking ($Fr = 0.25$), and walk-run transition ($Fr = 0.5$). During testing, randomization of the protocol by load and Froude number was done to avoid learning effects.

Overall, six parameters were analyzed. Force-sensitive shoe insoles (E.Q., Inc) were used to determine three gait parameters (sampling frequency 1000 Hz): cadence (number of steps per second), normalized stride length with respect to the subject’s leg length, and duty factor (stance time with respect to stride time). The leg angle at touch down, defined as the angle between the ground and a virtual line between the ankle and the hip, was derived from video data. In addition, heart rate (HR) was measured using a Polar chest transmitter. Moreover, the subjects’ individual comfort levels were assessed with a visual analogue scale ranging from 0 (not comfortable at all) to 10 (most comfortable condition imaginable). All parameters were analyzed for statistical differences using the General Linear Model (GLM) for repeated measures, followed by an analysis of simple effects. Significance was set at $P<0.05$.

![Figure 1: LBPP chamber (left) and harness system (right).](image1)

<table>
<thead>
<tr>
<th>$Fr$</th>
<th>0.09</th>
<th>0.25</th>
<th>0.5</th>
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<tbody>
<tr>
<td>BW = 100%</td>
<td>0.9 m/s</td>
<td>1.5 m/s</td>
<td>2.1 m/s</td>
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<tr>
<td>BW = 66%</td>
<td>0.7 m/s</td>
<td>1.2 m/s</td>
<td>1.7 m/s</td>
</tr>
<tr>
<td>BW = 33%</td>
<td>0.5 m/s</td>
<td>0.9 m/s</td>
<td>1.2 m/s</td>
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**RESULTS:**
For suspended walking within the LBPP chamber, cadence ($P<0.001$), normalized stride length ($P<0.001$), duty factor ($P<0.01$), and heart rate ($P<0.001$) all decreased significantly by reducing loading. In contrast, the leg angle at touch down increased with unloading ($P<0.001$). However, comfort was independent of the level of loading ($P=0.77$). Higher Froude numbers significantly increased cadence, normalized stride length, and heart rate ($P<0.001$ for these three parameters), whereas duty factor ($P<0.001$), leg angle ($P<0.001$), and comfort decreased ($P<0.01$) with higher Froude numbers.

For suspended walking using the harness system, cadence, normalized stride length, duty factor, heart rate, and comfort decreased significantly with reduced loading ($P<0.001$ for these parameters). As previously observed, the leg angle at touch down increased with unloading ($P<0.001$). In case of higher Froude numbers, cadence, normalized stride length, and heart rate increased significantly, whereas duty factor, leg angle, and comfort decreased with higher Froude numbers ($P<0.001$ for all parameters).

In comparing LBPP to harness supported unloaded walking, differences were found for the heart rate ($P<0.05$) and comfort ($P<0.001$), but not for cadence ($P=0.70$), normalized stride length ($P=0.81$), duty factor ($P=0.12$), and leg angle at touch down ($P=0.45$). Mean heart rate for all conditions was lower for LBPP (HR=96) than for the harness (HR=96). Comfort was higher in LBPP than for the harness (Figure 2).

![Comparison of comfort between LBPP and harness for all unloading conditions and Froude numbers.](image2)

**DISCUSSION:**
We found, as expected, that gait parameters were influenced by both body unloading and Froude number. Therefore, the normal gait pattern (expressed by change in gait parameters compared to 100% BW) is altered during unloading at a constant Froude number. In contrast to these findings, results from studies which maintain treadmill speed constant during unloading indicate that cadence and stride length are only slightly affected by body unloading$^{[3,4]}$.

LBPP and harness walking do not differ with respect to gait parameters. However, we documented that during unloaded LBPP ambulation, heart rate is significantly reduced compared to suspended harness walking, perhaps due to facilitation of venous return during LBPP ambulation. This finding is important if considering early walking exercise in orthopaedic patients with cardiovascular diseases. Furthermore, we found that walking within the LBPP chamber is significantly more comfortable than unloaded walking with the harness system. The observed discomfort during unloaded harness walking probably relates to high local stresses beneath the pelvis.

**REFERENCES:**