Vacuum Suspension and In-Socket Tissue O2

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INTRODUCTION

The presence of oxygen (O2) is one of the most important indicators of healthy tissue. Higher levels correlate with infection resistance (Hunt 1979) and faster wound healing (Niinikoski et al., 1972). Donning a lower limb prosthesis can compress residual limb tissue, restricting blood flow and reducing tissue O2. The compressive loads of standing and walking can further restrict blood flow. For lower limb amputees with poor circulation, failure to maintain sufficient tissue O2 may have serious, long-term consequences.

Vacuum-assisted suspension systems may alleviate some of these effects. The purpose of this study is to discover the effect of vacuum pressure on residual limb tissue O2 while resting, standing, and walking.

METHOD

Subjects: One active and healthy transtibial amputee provided informed consent to participate in this IRB-approved protocol (n=1; 32 ye, 72 kg, 1.8 m, 8.5 years post-amputation due to trauma). The subject’s existing prosthetic prescription included: a total contact modified patellar tendon-bearing socket and an elastomer liner (Easyliner Cushion; Alps) with a pin lock suspension.

Instrument: The ratio of oxygenated hemoglobin to total hemoglobin (expressed as percentage StO2) in the posterior compartment of the residual limb microcirculation was measured (0.5 Hz) using near infrared spectroscopy (Inspectra StO2 tissue oxygenation monitor; Hutchinson Technology).

Study Prosthesis: A custom silicon insert (Ohio Willow Wood) incorporating the StO2 sensor was placed on the subject’s residual limb. An elastomer liner (Alpha Max; Ohio Willow Wood) was fit over the sensor insert. A total surface-bearing suction socket with an elevated vacuum suspension (LimbLogic VS; Ohio Willow Wood) was then fabricated and fit over the sensor insert and liner. Vacuum pressures were precisely controlled with a vacuum pump (2545B-01; Welch), regulator (487; LJ Engineering), and software (Labview; National Instruments) to maintain target pressures within ±2 kPa with a direct connection to the socket port.

Procedures: Data collection began with a standard sensor and the subject resting in the prone position for 5 min. The prosthetist then placed the custom sensor insert on the subject’s residual limb, and the subject donned the prosthesis. The vacuum pressure was selected, and 5 min. was allowed for acclimation. The protocol continued with the following sequential activities: (1) 5 min. rest period in the prone position, (2) 5 min. standing, (3) 3 min treadmill walk at self-selected speed, (4) 5 min prone rest. The next vacuum pressure was selected and the protocol was repeated. Data was collected at vacuum pressures of -68, -34, -10, and 0 kPa in randomized order.

RESULTS

Residual limb tissue O2 during prone rest was 63% StO2. After donning the prosthesis, StO2 varied with vacuum pressure while resting, standing, and walking (see Table). During prone rest, decreasing vacuum increased StO2 and was best with no vacuum. While standing, vacuum increased StO2 compared to no vacuum (0 kPa). While walking (~1.4 m/s), increasing vacuum resulted in increased StO2. During post-walk prone rest, vacuum increased StO2 and was worse with no vacuum.

<table>
<thead>
<tr>
<th>Vacuum Pressure (kPa)</th>
<th>PRONE REST</th>
<th>STAND</th>
<th>WALK</th>
<th>PRONE REST</th>
</tr>
</thead>
<tbody>
<tr>
<td>-68</td>
<td>53±15</td>
<td>60±10</td>
<td>55±5</td>
<td>60±3</td>
</tr>
<tr>
<td>-34</td>
<td>59±2</td>
<td>63±5</td>
<td>51±8</td>
<td>61±5</td>
</tr>
<tr>
<td>-10</td>
<td>64±4</td>
<td>68±4</td>
<td>43±6</td>
<td>62±6</td>
</tr>
<tr>
<td>0</td>
<td>70±1</td>
<td>42±13</td>
<td>16±8</td>
<td>25±5</td>
</tr>
</tbody>
</table>

Table. Residual limb tissue O2 (mean ± std dev percentage StO2) while wearing a socket and liner at different vacuum pressures.

DISCUSSION

Depending on activity and history of activity, vacuum pressure may have a negative or positive effect. Prior to standing or walking, no vacuum resulted in the highest tissue O2. The situation was reversed after standing and walking; no vacuum resulted in the lowest tissue O2. Low vacuum was best during standing while higher vacuum was better while walking.

CONCLUSION

Vacuum suspension systems with activity- and history-dependent control may improve residual limb health.

REFERENCES