SpringStepper: An Alternative to Traditional Crutches
Jennifer Smith, Garrett Jones, Wm. Paul Gilson, Jeremiah Woodall, Matthew Clegg

Introduction

Auxiliary crutches are the most common type of crutch. They are cheap and readily accessible, which makes them a popular option. However, when used incorrectly they can cause a host of problems, including blood clots (Brooks) and nerve damage (Chang). Even when used correctly they can cause carpal tunnel syndrome and other injuries due to the large amount of force placed on the hand and wrist (Goh). Several different crutches have been created, but each comes with its own issues (Malkan). The SpringStepper was evaluated in two ways. First, a small, unbiased group was asked to try the crutch and provide feedback. Second, after implementing the suggestions from the survey, the final design was tested using force sensitive resistors.

Survey

Sixteen people tested the prototype and rated the following on a scale from 1 to 10: (1) overall appearance, (2) comfort when walking, (3) ease and comfort of sitting, (4) support, (5) ease of movement on flat ground, (6) ease of movement on stairs, and (7) range of movement. The average score from each question is shown in Table 1.

Objectives

Design a more effective crutch that is:

• Hands-free
• Easy to use
• Comfortable

In addition, it must:

• Distribute weight in a way that does not cause additional injury
• Keep a normal walking motion to prevent muscle loss

Evaluation Criteria

The following are the evaluation criteria for the SpringStepper.

1. Stabilizes knee and prevents lateral wobbling
   • Less than 5° in either lateral direction
2. Absorb 30% more force compared to axillary crutch
3. Adjustable for a variety of heights and limb lengths within the bounds of a slightly taller-than-average person (71” – 76” and 180lbs to 220lbs)
   • 2” of height adjustability
4. Straps around thigh with adjustable circumferences between 23”-26”

Design Process

Below is a general outline of the design process used to create the SpringStepper. The fabrication stage was repeated 8 times as new decisions were made. After a customer survey, the design of the straps and padding was changed one more time but the general body of the crutch was kept the same.

Eight prototypes were created during the design phase of this project. The three shown here detail the pivotal decisions that were made.

1. The first prototype was made of schedule 40 steel pipe with a wall thickness of 0.133 inches. The pipe was too heavy and the desired bends at the bottom of the crutch could not be formed. After further testing, a wall thickness of 0.035 in was chosen.
2. The second prototype implemented a bend at the knee along with a bend at the ankle to add support throughout the whole leg. There was also a cross support beam at the top of the tibia to support the knee and shin. The sling was chosen to distribute the force more evenly throughout the shin.
3. The third prototype used a sling instead of the cross support beam after the beam was shown to place too much force on the upper tibia and knee. Force sensor analysis showing a significant reduction in force in the shin and thigh.

Final Design

The final prototype uses a shin plate instead of the sling. After testing, the sling was shown to still add too much force to the upper tibia. The shin plate covers a six inch span of the lower leg, distributing the force placed on the shin over a larger area. A strap was also added near the knee to aid the user when taking the stairs. To further increase the comfort of the user, padding was added to the underside of each thigh strap and round pads were added around the shin and ankle crossbars.

Results

The SpringStepper absorbed 120% more force than axillary crutches.

The following are the evaluation criteria for the SpringStepper.

1. Stabilizes knee and prevents lateral wobbling
2. Absorb 30% more force compared to axillary crutch
3. Adjustable for a variety of heights and limb lengths within the bounds of a slightly taller-than-average person (71” – 76” and 180lbs to 220lbs)
4. Straps around thigh with adjustable circumferences between 23”-26”

Table 1. Approximate weights and costs of the frame from various materials.

<table>
<thead>
<tr>
<th>Material</th>
<th>Weight</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>AISi1003 Steel</td>
<td>6.76 lbs</td>
<td>$79.33</td>
</tr>
<tr>
<td>1060 Aluminum Alloy</td>
<td>2.66 lbs</td>
<td>$35.25</td>
</tr>
<tr>
<td>Hexcel AS4C Carbon Fiber</td>
<td>1.93 lbs</td>
<td>$266.58</td>
</tr>
<tr>
<td>PVC Rigid</td>
<td>1.56 lbs</td>
<td>$4.58</td>
</tr>
<tr>
<td>Ti-SiAI-2.55Sn Titanium Alloy</td>
<td>4.06 lbs</td>
<td>$240.00</td>
</tr>
</tbody>
</table>

Table 2. Survey feedback

<table>
<thead>
<tr>
<th>Question</th>
<th>Mean Score</th>
<th>Std. Dev.</th>
<th>Range</th>
<th>Min</th>
<th>Max</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.81</td>
<td>1.285</td>
<td>4</td>
<td>6</td>
<td>10</td>
<td>N/A</td>
</tr>
<tr>
<td>2</td>
<td>6.38</td>
<td>1.452</td>
<td>6</td>
<td>3</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>7.44</td>
<td>1.540</td>
<td>6</td>
<td>4</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>7.31</td>
<td>1.261</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>6.00</td>
<td>1.408</td>
<td>5</td>
<td>4</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>6</td>
<td>7.19</td>
<td>1.236</td>
<td>5</td>
<td>5</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

Participant height varied from 70” to 76” and the thigh straps adjusted from 23” to 27” circumference, showing higher adjustability than anticipated.

When asked if they would rather use the SpringStepper or traditional crutches, 14 out of 16 said they would rather use the SpringStepper.

Special thanks to the USU Department of Biological Engineering, Randall Chesley of the USU Department of Agricultural Systems Technology and Education, Jackson Graham and Spencer Wender of the USU Department of Mechanical and Aerospace Engineering, Eddie Bressel and Chris Dakin of the USU Department of Kinesiology and Health Science, Kevin Mann of LightningKite, Greg Duncan of Rocky Mountain Artificial Limb & Brace, Amy Suriga of Freedom Innovations, Ryan Perry of Logan Physical Therapy, and Jay Cottle of Bear River Valley Hospital.

Acknowledgements

Brooks A. L.; Fowler S. B.; Auxiliary Artery Thrombosis after Prolonged Use of Crutches; Journal of Bone and Joint Surgery; 1964; 46(4)
Goh I. C. H.; Toh S. L.; Bose K.; Biomechanical Study on Axillary Crutches During Single-Leg Swing-Through Gait; Prosthetics and Orthotics International; 1986; 10, 89-95