Step by Step: A Comprehensive Approach to Stair Climbing Assistance

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Background

- In 2009, 120,000 patients visited the ER for lower extremity injuries [1].
- Below-the-knee injuries often require extended recovery of up to 14 weeks [2].
- Mobility-impaired patients in wheelchairs cannot navigate the stairs in their homes given existing solutions, such as a garden bench, the iWalk device, and crutches.

Problem Definition

- **Challenges in Neuro-Rehabilitation for Mobility-Impaired Patients with Limited Weight-Bearing Capacity:** Supporting patients with weight-bearing restrictions during the transition to home environments, particularly when navigating steps, poses significant difficulties for physical therapists.
- **Limitations of Current Solutions:** Non-adjustable height, absence of a handle for ease of use, instability, discomfort, and lack of user-friendliness.
- **Need for Improved Equipment:** There is an urgent need for a medically designed, safer bench for older, weaker patients who cannot use existing solutions to navigate stairs.

Design Criteria & Specifications

Design a device that aids individuals with a below the knee weight bearing restriction in ascending and descending stairs.

The bench must meet the following quantitative specifications:
- Withstand a maximum load of 300 lbs.
- Low center of pressure displacement and path length under anterior-posterior and medio-lateral movement.
- Device weight under 5 lbs.
- Adjustable bench height.
- Accommodate OSHA standard stair tread of 9 inches and riser height of 9 inches [3].
- Adhere to target production cost of less than $100.

Figure 1. Current rehabilitation bench in use [4]: A patient with a non-weight bearing limb navigating the stairs. The limitations include lack of adjustability and medical design.

Final Design

(a)

(b)

Figure 2. Final prototype of the assistive device:
(a). Bench and handle made from wood, supported by L-brackets, and topped with a neoprene cushion for added comfort.
(b). Adjustable column with multiple holes spaced at 1-inch increments to accommodate tibia lengths from 15 inches to 18 inches, using a pin and sliding mechanism.

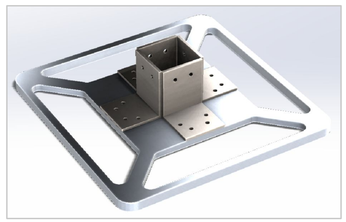


Figure 3. Wide aluminum base to expand the distribution of mass:
- Ground contact points located on the outer edge, with a raised central portion that centralizes the mass above the base, ensuring a stable structure on irregular surfaces.

Testing

Figure 4. Assessing stair ascension stability:
- Each participant performed three trials each for three conditions: Control (top left), Stair-Assist Bench (SAB) (top right), and the Hands-Free Crutch (HFC) (bottom).
- A force plate was used to collect center of pressure (COP) measurements to assess postural stability.

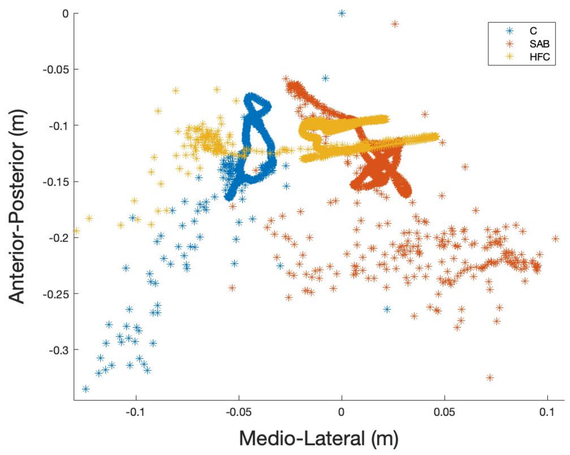
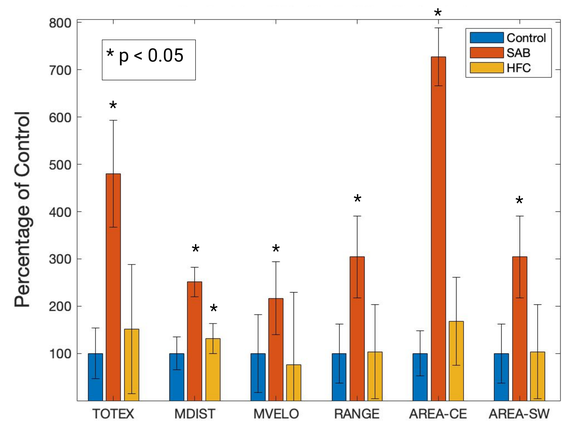


Figure 5: Stabilogram depicting the COP trajectories during a one-step stair ascent performed by a single subject across three interventions:
- Tightly clustered data points suggests greater postural stability.
- The SAB and HFC interventions show more dispersed trajectories, indicating variable postural stability relative to the Control.

Results



Measure	Description
MDIST (cm)	Average distance from the mean COP
TOTEX (cm)	Total length of the COP path
RANGE (cm)	Maximum distance between any two points
MVELO (cm/s)	Average velocity of the COP
AREA-CC (cm^2)	95% confidence circle area
AREA-SW (cm^2/s)	Sway area

Figure 6. Investigation of SAB and HFC interventions on COP measures relative to a control condition, normalizing all data to percentage values based on the control group.
- Statistical analysis using one-way ANOVA indicated significant differences (*p < 0.05) in specific measures, suggesting variations in postural control strategies.
  - All measures showing significant increases (*p < 0.05) for the SAB compared to the Control.
  - Significant increase (*p < 0.05) in MDIST measure for the HFC compared to the Control.

The SAB intervention influences COP measures significantly when compared to the Control, indicating instability that required alterations in postural control mechanisms.

Future Work

Fabrication
- Improve the connection between the base and the platform.
- Refine the adjustable column design to enhance the precision of fit between the telescoping inner and outer sleeves.
- Fabricate remaining components from aluminium.
- Improve comfortability of the handle by changing its shape.
- Design a stair lip deflection mechanism to improve the devices usability.

Testing
- Perform testing with a larger sample size to collect qualitative data on device functionality.

References & Acknowledgements

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