(Compact Ankle Rehabilitation Device)

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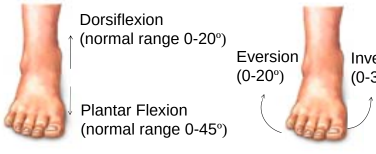
ANKLE BACKGROUND



DEVICE NEED

An ankle rehabilitation device with a virtual reality interface is needed for use with gait-impaired neurological patients in a clinical research environment. The research device will be used for future development of a more compact and affordable product to be used at a patient's home. The ability to measure force and track ankle position is needed for clinical research purposes. Patients expected to benefit from this device include victims of stroke, multiple sclerosis, brain trauma, Alzheimer's disease and cerebral palsy.

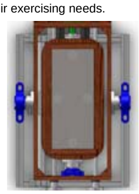
Design Specifications

Design Specification	Corresponding Values
Materials	Must be lightweight and cumulatively less than 40 lbs, and no more than $200-300
Size	No more than 18" at longest point
Weight (mobility desired)	Be lightweight and cumulatively less than 20 lbs
Degrees of Freedom	2 Degrees of Freedom
Functions	
Dorsiflexion	Motion Sensing and Resistance.
Plantarflexion	Motion Sensing and Resistance.
Inversion	Motion Sensing and Resistance.
Eversion	Motion Sensing and Resistance.
Dorsiflexion	0-20°
Plantarflexion	0-45°
Inversion	0-30°
Eversion	0-20°

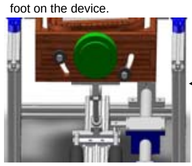
Design Specification	Corresponding Values
Measurement System – Motion	
Accuracy	Able to track motion in real time
Measurement System - Position	
Range	360°
Resolution	1024/revolution
Virtual Reality	
Feedback	Graphical user interface
Data Logging	Yes
Safety	Must be stable to prevent falls and have no unsafe pinch points
Force	
Max Weight Supported	250lb
Research	
Polhemus	Device must be minimally ferrous
Force sensing	

Sub Systems

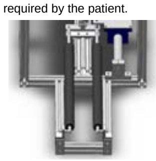
Adjustable mechanical stops allow the patient to change the range of motion of the device to better fit their exercising needs.



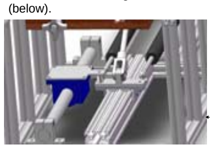
Four load cell sensors are placed beneath a Plexiglass plate on the platform. The sensors allow the physical therapist to calculate the center of pressure of the patient's foot on the device.



An adjustable MRF damper allows for resistance in eversion and inversion. The appropriate adjustment can either increase or decrease the amount of effort required by the patient.



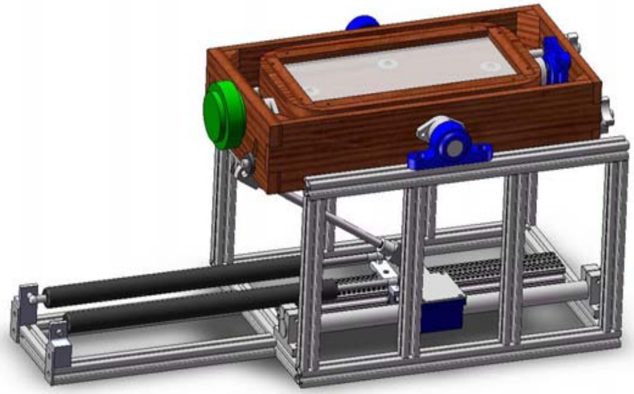
Adjustable linear dampers resist the motion of plantar- and dorsiflexion. The dampers are attach to the mounting device (below).



The rotational motion of the platform in plantar and dorsiflexion is translated to linear motion via a clevis arm. A second track with a linear bearing prevents vertical motion of the track.

ABSTRACT

Ankle exercises are a key aspect of physical therapy for neurological patients suffering from gait impairment. The ability to produce adequate range of motion and control muscle forces in both weight bearing and non-weight bearing positions are important components of gait and balance function. During rehabilitation training, it is often difficult for the therapist to quantitatively assess the patient's performance and provide feedback, especially during dynamic weight bearing exercises. The NU Ankle was invented to meet this need. The device can measure the applied forces and position of the patient's ankle through its full range of motion, and can be used in sitting or standing positions. Two training modes have been developed: 1) Stable – this mode acts like a force platform and measures center of pressure (COP) for weight shifting and balance exercises; 2) Moving – in this mode, the ankle moves freely about either or both axes, and the motion is displayed in a 3D virtual environment (VE) via a motion tracking interface. Resistance may be added to the ankle motions. The VE program provides visual feedback and motivation for the patient during therapy. A goal for the future is to develop a more compact version of the NU Ankle for home rehabilitation use.



Nu Ankle achieves full range of motion of an ankle by having two axes of rotation. The eversion/inversion axis is created along the centerline of the platform. The plantar- and dorsiflexion axis is created along the pillow block rotary bearings. A series of subsystems allow for the damping, sensing, and motion restriction of the device.

Plantar Flexion

Dorsiflexion

Inversion

Eversion

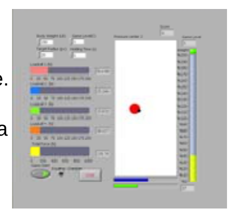
PROTOTYPE

USER INTERFACE

The user interface has two training 'modes':

1) Stable – Force feedback is displayed using Labview software. Four sensors are used to find the center of pressure of the foot. This information can be used for a variety of games, which promote weight shifting and dynamic balance.

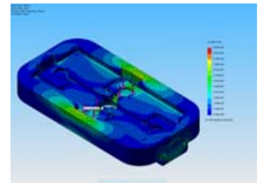
2) Moving – Position feedback is displayed using a Polhemus sensor, as shown in Testing and Calibration. This feedback can be used for range of motion exercises as well as to track progress.



1) Stable Mode - A weight - shifting game interface is shown above. The red dot changes location in the white box every 30 seconds, and the user has to place their center of pressure (black dot) within that time.

FINITE ELEMENT ANALYSIS

A series of finite element analyses were performed to determine the optimal expansion element dimensions.



Preliminary FEA was performed on the wooden components of the tilt-maze model. Material properties for American Red Oak were used and the worst-case scenario of a neutral position load at the center of the pressure-plate platform was considered. A screenshot of the highest expected stress case is above.

Load, Left Sensor (lbs)		125
Load, Right Sensor (lbs)		125
Load, Front Sensor (lbs)		0
Load, Rear Sensor (lbs)		0
Max VM Stress location		Shaft-Mount Interface
Max VM Stress (ksi)		4.784
Front Shaft Reaction	x	-236.89
	y	124.88
	z	0.27338
Rear Shaft Reaction	x	236.89
	y	124.98
	z	-0.2448

TESTING AND CALIBRATION

2) Moving Mode - the Polhemus sensor (3D motion tracking device) is used to map ankle motion to a disc in a virtual reality display

When the patient performs plantar flexion, the virtual disc (seen in green) moves downward in sync with ankle. The wireframe disk is used as a teaching guide for the patient to follow. The patient can be scored by the program based on their performance.

FUTURE WORK

- Further testing with the force sensors and Polhemus sensor will ensure the device is capable of increasing neurological patient's ankle and gait function.
- Future generations of this device will be constructed of molded plastics to reduce risks associated with having wood in a medical environment and decrease the expense and weight of the device.
- Replacing the linear dampers with a second MRF will reduce the size and complexity of the device.
- Replacing the Polhemus sensor with potentiometers will reduce the overall cost of the device to allow for home use.