

# Development of a Body Weight Support System Used for Gait Training (Part II)

Team #28

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**Abstract**—Dr. Hamid Bateni has a particular research interest in studying the gait and posture of patients with limited mobility, but a lack of equipment hindered his ability to conduct the necessary gait training studies. A device that would allow patients to therapeutically learn how to walk with an efficient gait under partial weight bearing conditions was needed. Previous studies found that partial weight bearing during gait training provides patients with a better likelihood to learn an efficient gait [1]. This project developed a gait training system prototype consisting of two subsystems: a horizontal position system and a vertical support system. These subsystems, in conjunction with their own sensors and control systems allow the prototype to follow the patient overhead while providing a constant amount of vertical support on the patient. A digital display also allows researchers to change important parameters during the study, as well as, immediately see the results of their studies. Additionally, several safety measures were implemented into the design of the prototype as patient safety is of the utmost importance in the clinical setting in which the prototype will operate.

## I. INTRODUCTION

There are several different gait training systems already on the market with the capability of providing partial weight bearing, however, these systems often cost several thousands of dollars. The prototype created aimed to provide similar capabilities of existing systems while remaining sufficiently more cost efficient. To provide a patient with both a beneficial and safe gait training session, the device must follow the patient overhead as they walk while providing a constant vertical support. To accomplish this, the prototype has a subsystems dedicated to each of these tasks. Each subsystem has its own sensor and control system to sense the current state of the system, process the information provided by the sensors, and actuate the subsystem. The horizontal position subsystem uses a potentiometer connected via swivel rod to the plate overhead of the patient to detect the angle of tilt of this plate. This information is then used to actuate a stepper motor which drives the trolley along the I-Beam to keep the system directly overhead of the patient. The vertical support system utilizes a load cell to measure the force experienced by the patient and its feedback controls the vertical movement of the pneumatic cylinder. The pneumatic cylinder moves either up or down to counter the patient's change in center of gravity during their gait, in order to maintain a constant tension in the cable attached to the patient.

## II. METHODS

The horizontal position subsystem must enable the system to follow the patient overhead while minimizing the amount of haptic feedback experienced by the patient. Previous prototypes used sensors that only had an “on” or “off” signal, thus making quick, dynamic responses to patient movement not possible. This prototype used a potentiometer connected via swivel rod to the plate attached to the patient overhead to measure the angle of tilt of this plate. Tilting of the plate indicates patient movement and the potentiometer sends a signal to the control system. The Arduino-based control system actuates the subsystem by driving a motor shaft that rotates a winch, causing the cables wrapped around the two winches to move horizontally along the I-Beam. A trolley on the I-Beam, in which the entire system is mounted to, is pushed or pulled via these cables to match the motion of the patient. Using the angle of tilt of the plate, rather than, an “on” or “off” signal makes dynamic response possible. This enables the trolley to not only move in the same direction as the patient, but move at the same speed as the patient as the trolley's speed is proportional to the magnitude of the angle of tilt.

The vertical support subsystem must maintain a constant vertical support load on the patient as they walk. For the vertical support on the patient to be constant, the subsystem must be able to dynamically respond to the changes in a person's center of gravity (COG) during the gait cycle.

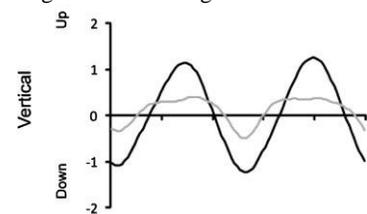


Figure 1: Vertical COG Displacement during the Gait Cycle [2]

The prototype measures the bodyweight of a patient using a load cell attached to the harness of the patient that relays its signal the control system. The control system then actuates the pneumatic cylinder by opening one of the two solenoid valves causing the rod of the pneumatic cylinder to either retract or extend. When a solenoid valve is opened, air is released from the upper or lower chamber causing that chamber to depressurize. This depressurization moves the “piston” rod in its direction thus retracting or extending the rod to change the amount of vertical support on the patient. The rod of the pneumatic cylinder would retract when the patient's COG rises and extend when the patient's COG moves downward. This is

necessary as the load cell will measure a lower value when the person's COG rises than when the person is standing still.

A third Arduino-based control system allows for the researcher to interact with the prototype in real-time using a digital display. The researcher can change the amount of vertical support on the patient using this interface. The amount of vertical support is also plotted over the duration of that gait training session and can be used to verify that the vertical support experienced by the patient is both consistent and constant.

### III. RESULTS AND DISCUSSION

Many modifications to this project had to be made in order to produce a functioning prototype within the time and budget constraints. Essentially, the produced prototype is intended to be a proof-of-concept design only and does not meet the minimum requirements in order to be a fully functioning research tool. Further design with an expanded budget is required in order to achieve such a tool. However, our design does exhibit the functionality of the initial goal.

Initially, planned prototype testing involved operating the prototype on a gantry crane while providing partial weight bearing to a person during gait training, however, access to the lab was not possible due to recent events. Instead, the goal of testing steered toward proof of concept by operating the prototype on a 4' x 5' I-Beam using weighted object such as a 25 lb. plate.

The vertical support subsystem was tested by hanging objects of different weights from the system and analyzing the graph of the vertical support on the object over the time of the study.

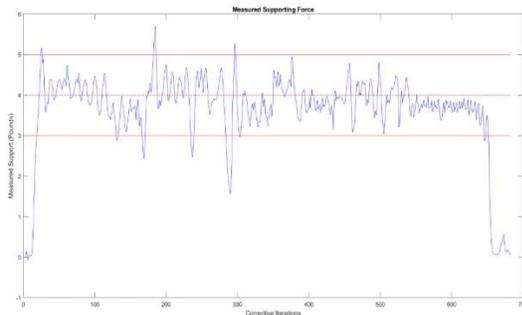


Figure 2: Plot of the Vertical Support Provided vs. Time for Various Weighted Objects

The center of gravity of these objects is constant, so theoretically a horizontal line across the plot would indicate a constant and consistent vertical support was provided by the prototype during the trial. Actual testing showed a plot with slight fluctuations from a straight horizontal line, but most fluctuations fell within the threshold of 1 lb. Only being able to test lighter objects on a much shorter I-Beam made proper calibration of the vertical support subsystem very difficult, however, it can be reasonably inferred that the prototype operated with an accuracy within the threshold specified by Dr. Hamid Bateni.

Testing of the horizontal position subsystem proved inconclusive as the wooden I-Beam did not allow for enough horizontal displacement to properly test the subsystem's response to the motion of the patient. Had the full gantry crane been available for testing, a patient under partial weight bearing would have been used to measure how long it took the subsystem to "correct" itself so that the plate was once again vertical overhead of the patient. Preliminary testing on the wooden I-Beam show promising results as the horizontal position system adjusted quicker and at higher speeds when the angle of tilt of the plate was increased, however, it would be premature to declare that this indicated that the haptic feedback

experienced by an actual patient would be minimal when using the prototype.

### IV. CONCLUSION

The prototype has the ability to dynamically adjust itself to maintain a constant vertical support as the center of gravity changes during the gait of the patient. It achieves this while showing promise in its ability to minimize the haptic feedback experienced by patients. Limited testing prevented of conclusively determining the prototype's performance as similar to other products on the market. However, the project was able to create a proof of concept design for the prototype at much lower cost to these similar products.

### V. ACKNOWLEDGMENTS

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### VI. REFERENCES

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