

DIY In-Home Anti-Gravity Harness

Background Report

9/30/2016

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1 Background

1.1 Introduction

Children with disabilities, especially those with limited mobility, find difficulties later in life with socialization and cognitive development. A study found that additionally, children less able to interact with their environments are associated with poor performance on cognitive activities and learning tasks [1]. The same study found that increasing the number of strides a day with disabled toddlers were linked to greater social association.

Cerebral palsy (CP) is the most common motor disability in children, with every 1 in 323 child born with it [2]. It is a congenital disorder that affects the patient's posture, muscles, and movement. There are no cures for CP, and the associated treatments are often time and money intensive and can last for the entire lifetime of the child. Every case of CP is unique as each patient experiences different physical impairments, including what limbs are affected and to what extent. Children with CP under the age of 5 are often totally restricted in mobility, depending on parents or siblings for all movement or interaction, which negatively affects their developmental outcomes in the future.

This project seeks to formulate a solution to the limited mobility of disabled children by designing a Do-It-Yourself (DIY) anti-gravity balancing system. The sponsor, Dr. Kyle Winfree, is part of the Informatics and Computing division of NAU that aims to create wearable systems that aid everyday life. The project seeks to be DIY to assist parents of disabled children who may be limited by time, money, or training when it comes to improving the socialization of their kids. To fully complete the capstone project, the team will create a device that reduces the body weight of disabled children, allowing them to interact with the world around them, without requiring an advanced degree in engineering or physical therapy for the parents.

1.2 Project Description

The project description from the client was given verbatim as follows:

Children with limited mobility often do not receive the much needed exposure to socialization to appropriately cognitively develop. Existing research shows that enabling young children with self-control of their own environment can have meaningful impacts on the long term outcomes given such impairments as cerebral palsy or muscular dystrophy. One place to start and increase mobility is in the home. Imagine you are a toddler, who isn't yet able to walk or crawl on your own, and you want play with a toy on the other side of the room. How the heck is that going to happen if you cannot walk or crawl?

The goal of this project will be to design and fabricate a Do-It-Yourself in-home gravity balancing harness system that parents of children with movement disabilities can build with limited resources.

1.3 Original System

As this is an entirely new project there were no original systems the team will improve upon.

2 Requirements

2.1 Customer Requirements

After conferring with the client and the group, nine governing customer requirements with weights from 0-10 were produced and can be viewed in the table below.

Table 1. Customer Requirements and Weights

Customer Requirement	Weight (x/10)
Safety: Low choking/entanglement risk	10
Ease of Assembly: Avoid machining, complex parts	7
Adjustability: Accommodate different sized children or growth	5
Durability: Materials pass various strength or fatigue tests	7
Size: Is unobtrusive and allows user to interact freely	6
Comfort: Refrain from using coarse/irritating materials	8
Cost: Keep under target cost	7
Workspace Size: Size user has available	6
Aesthetics: Contain multiple colors and child friendly designs	9

Among the top weighted sponsor requirements include safety, aesthetics, and comfort. Our rationale for these requirements had derived from the team's concern for creating a product that will positively change lives of children who have Muscular Dystrophy (MD) and various other mobility issues. Part of the success for our design will depend on parents of children putting trust into our harness system to not harm their kids in any way. This causes our safety weighting to be our most prioritized trait with a rating of a 10. Comfortability and aesthetics had been our next highest ratings of 9 and 8 respectively. The anti-gravity harness system will be used for time periods of up to four hours ($T \leq 4$). This forces comfort duration to be an important factor to test in our design. Lastly, aesthetics was an addition added by Dr. Winfree himself from his knowledge of current existing competition baby products. The team experienced delays in meeting the project's client due to schedule conflicts, so the first six customer requirements were developed and voted on by the team. After meeting the client, the

requirements of cost, aesthetics, and workspace size were added to **Table 1** along with the assigned weights.

2.2 Engineering Requirements

From the customer requirements, a series of engineering requirements with targets and tolerances were developed in **Table 2**. Each customer requirement was paired with physical parameters that we could measure and calculate to ensure our customer requirements are met. These measurable specifications will enable the team to start prototyping and testing different designs for our harness system.

Table 2. Engineering Requirements

Customer Requirement	Correlating Engineering Requirement
Safety: Low choking/entanglement risk	<ul style="list-style-type: none"> ● No Sharp Points
Ease of Assembly: Avoid machining, complex parts	<ul style="list-style-type: none"> ● No Pinch Points ● Less than 20 parts
Adjustability: Accommodate different sized children or growth	<ul style="list-style-type: none"> ● Socket Sliders
Durability: Materials pass various strength or fatigue tests	<ul style="list-style-type: none"> ● Handle weight loads of 40 pounds
Size: Is unobtrusive and allows user to interact freely	<ul style="list-style-type: none"> ● Fits in 5ftx5ftx5ft Volume Space
Comfort: Refrain from using coarse/irritating materials	<ul style="list-style-type: none"> ● Elastic Materials
Cost: Keep under target cost	<ul style="list-style-type: none"> ● < 300 Dollars
Workspace Size: Size above user	<ul style="list-style-type: none"> ● Fits in 10ftx10ftx10ft Volume Space
Aesthetics: Contain multiple different colors	<ul style="list-style-type: none"> ● Gloss Finished Paints

The engineering requirements are subject to change after the next client meeting.

2.3 House of Quality

The House of Quality (HOQ) was a organized way to present the customer and engineering requirements (**Figure 1**).

1	House of Quality (HoQ)											
2												
3	Customer Requirement	Weight	Engineering Requirement									
4	1. Safety	10	Less than 20 parts									
5	2. Ease of Assembly	7	No Pinch Points	8	8							
6	3. Adjustability	5	Fits in 5ftx5ftx5ft Volume Space			6						
7	4. Durability	7	Socket Sliders									
8	5. Size	6	No Sharp Points					7				
9	6. Comfort	8	Handle weight loads of 40 pounds				8		6			
10	7. Cost		Elastic Materials									7
11	8. Workspace Size		Fits in 10ftx10ftx10ft Volume Space							7		
12	9. Aesthetics		Gloss Finish Paints								10	
13	10.		< 300 Dollars									
14	[add or remove CR rows, as necessary]											
15	Absolute Technical Importance (ATI)											
16	Relative Technical Importance (RTI)											
17	Target(s), with Tolerance(s)											
18	[add or remove T/T rows, as necessary]											
19	Testing Procedure (TP#)											
20	Design Link (DL#)											

Figure 1. House of Quality

The HOQ will continue to provide an organized way to begin evaluating any potential designs and existing devices for adherence to the project guidelines.

3 Existing Designs

3.1 Design research

A series of 3 existing rehabilitation devices (G-Trainer, ZeroG, and Kickstart) were researched in order to educate the team about existing anti-gravity systems.

3.1.1 G-Trainer

The G-Trainer is a rehabilitation device that uses air pressure to unload weight from a patient's lower body and enables them to run on a treadmill with reduced impact forces (**Figure 2**). The G-Trainer sees use in military hospitals, universities, and on professional athletics teams as a way to relearn proper gait and balance without fully loading an injured body part.



Figure 2. G-Trainer Anti-Gravity Treadmill [3]

The integrated treadmill system can support up to an 80 percent reduction in bodyweight without using harness that can become uncomfortable or chafe patients [3]. Special shorts are worn to integrate with the airtight enclosure, using air pressure to adjust the amount of loading experienced by the legs. The system is as comfortable on the user as water training, but allows the leg swing to mimic above ground locomotion, which contributes to less impairment of normal joint movements. Studies showed that a reduction of 20% body weight did not alter metabolic responses when using the treadmill, proving its ability to maintain fitness during rehabilitation [4].

The main goal of the developing company (Alter-G) is to create a more affordable product in order to make the G-Trainer a standard in rehabilitative care. There are additional plans to create a similar product for children, to target the population suffering from cerebral palsy or other disorders.

3.1.2 ZeroG

The ZeroG system is an over ground body-weight system that allows rehabilitation patients to practice daily behaviors while not carrying their entire body weight (**Figure 3**).



Figure 3. ZeroG Trolley System [5]

The entire system consists of a harness for the patient with support for the groin, hips, chest, and shoulders, a spreader bar to distribute weight, and a trolley connected to an adjustable ceiling track. The trolley tracking system supports the patient without holding them back and is accurate to less than 3 degrees, increasing its ability to prevent falls in the patient [5]. The setup is capable of supporting 400lbs statically and 200 lbs. when moving dynamically [6].

The ZeroG product is more appealing to conventional therapists and users because it allows for a variety of motions to be tested, including: sit to stand, climbing stairs, and walking on a curving track. These options have more real life functionality than other rehabilitation setups that depend on lateral movement on a treadmill with only the ability to change speed or incline.

3.1.3 Kickstart

Kickstart is a hip-leg exoskeleton that uses tendon and spring technology to enable stroke survivors learn to walk again. **(Figure 4).**

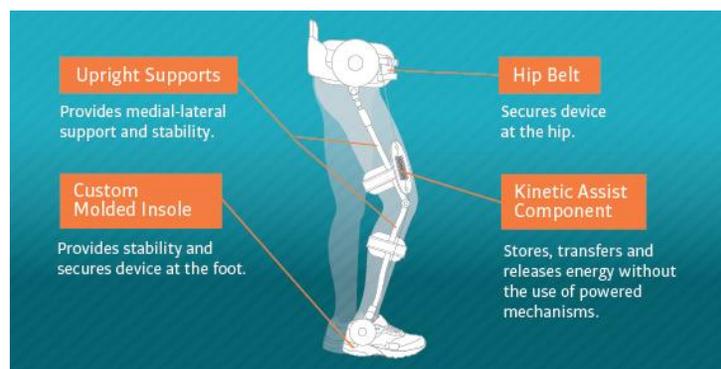


Figure 4. Kickstart Powered Assistance [7]

Cadence BioMedical, developer of Kickstart, market the technology as useful to those who have been paralyzed or cannot walk, even years after the incident that left them immobilized. The Exotendon is the core technology behind the device and allows energy to be stored and expended with each step the user takes [7]. The level of assistance can be set by the user or physical therapist to carefully guide the

patient to walking on their own as much as possible. Many stroke survivors are afflicted with foot drop, which causes the foot to drag on the ground unless the patient dramatically adjusts their hip positioning with each step. This behavior leads to unequal strain on each side of the body, which Kickstart seeks to address by including a foot plate and external ankle joint to assist users with keeping their foot oriented properly. The combination of an external frame with powered assistance makes the Kickstart system extremely accessible for patients with limited mobility.

From the preceding rehabilitation devices, the team was able to develop three system level designs that would eventually be broken down into subsystems.

3.2 System Level

System level design was developed with the researched existing devices in mind as a way to direct the design process.

3.2.1 Existing Design #1: ZeroG System

ZeroG system helps the child to improve their walk, balance and protect the user from falls. Moreover, the system provides a dynamic support so that it is more safe. The harness has a dynamic support so when the child is set in the harness the pressure will be balanced between the harness and the spreader bar without placing undue stress on any portion of anatomy. The ZeroG system can statically hold heavy weights and can be simple to set up after the ceiling mounted track has been installed. This system could be improved as a DIY project by getting the ceiling track from alternative sources, as the structural integrity for supporting a child's weight is different than a system designed to hold 200lb adults.

3.2.2 Existing Design #2: G-Trainer

The G-Trainer it is not as comfortable as ZeroG system because the patient cannot move freely, which is especially important in children of a young age. The G-Trainer can hold 80% of body weight without the pinching of a harness that could poorly fit a child patient. This device could reduce the injury potential through its even support of the center of gravity. The G-Trainer has an excellent body weight support system coupled with an unattractive limited mobility through the treadmill. If used, the system would need to be adapted to allow the child to move freely through their environment in all directions.

3.2.3 Existing Design#3: GlideCycle

GlideCycle is a bicycle that supports the pelvis without the application of pedaling to create motion [8]. The seat in GlideCycle is comfortable and can carry almost 90% of the body weight up to 230 lb. The user can move their legs freely about the hip without creating stress on the joints. Unfortunately this design has no back support, which is crucial for a child with limited muscular control. By adding a back support, seat belt, and increasing the number of wheels, the system could be more appropriate for a child with cerebral palsy.

The next step in the design process was breaking down a viable system idea into its subsystem components.

3.3 Subsystem Level

To complete the subsystem level designs the team completed a functional decomposition of the entire project (**Figure 5**).

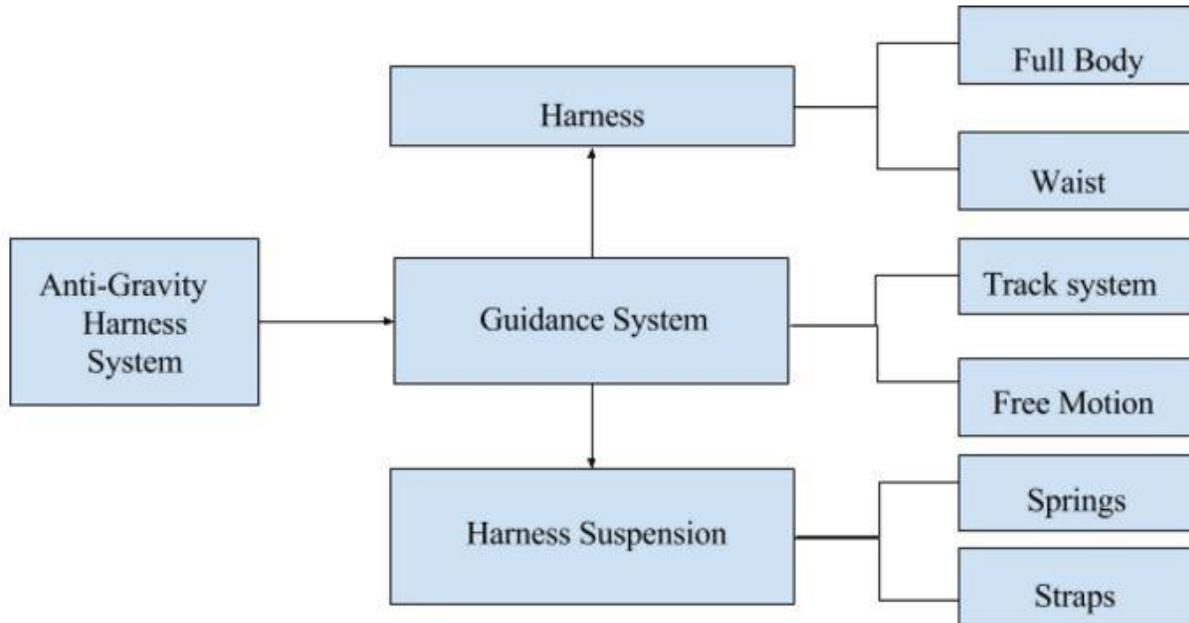


Figure 5. Functional Decomposition of System Level Design

The entire system was broken down into the following subsystems: Harness, Guidance System, and Harness Suspension.

The harness was categorized as being either a full body harness or a simple waist harness. A full body harness would be similar to the support seen in the ZeroG system. This full body harness helps reduce the body weight of the user at the groin, hip, chest, and shoulder level in order to reduce the amount of pressure on a patient needing a high percentage of body weight support. The simple waist harness would benefit users if they can handle walking almost all of their body weight but have troubles with weakness in the legs and can be supported by some outside system. The waist harness would provide the user with less coverage of the body which would be beneficial for some users with increased mobility while the full body harness would provide the necessary protection of the user needing extensive assistance.

The guidance system was broken down into a guided track system or free motion. The ceiling track system as seen in the ZeroG system allows the user to follow the path in the direction that the track system was installed. The free motion guidance system is more of a self stabilizing harness in which the user is not set to walk on a specific path but has the ability to roam while wearing the harness. The way ceiling track benefits the user through increased security in being able to avoid falls that could arise in a free roam system. The upside to unrestricted motion is that the user is more easily able to interact with the environment in any way they please, potentially increasing cognitive development.

The suspension for the harness was broken down into using springs or straps. Springs can provide a reduction in body weight from beneath the user while straps would provide that same reduction but from above the user. Springs are utilized in the Glidecycle beneath the seat to allow the user to stand

above a partial seat that reduces their body weight which assists the user in walking around. Straps provide this same support but can be more assistive to the user by supporting them entirely.

The subsystem breakdown should prove most beneficial to the design process because the different tasks can be divided up in a way that involves all team member's engineering knowledge.

4 Conclusions and Future Work

The first steps of the project served to educate the team about the scope of the project as well as the requirements of the client. Through the research of existing related designs, a system level view of the project was developed before being broken down into available subsystems.

The next step in the project is to use all the available information to start developing design concepts in the form of sketches. These design concepts will then be rated according to the design criteria contained in the HOQ (**Figure 1**) and checked with the client to ensure satisfaction at all levels.

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