5. Optimal Design Zip Line Walking device

Introduction

Elysa is a six year old girl who was born premature. This has affected her neural development for motor coordination and her muscle development. She currently has the ability to complete simple tasks and has the capacity to learn and gain strength for more complicated tasks. However, her neural development for motor function limits her.

All of the devices in the project are going to help her muscles develop, as well as increase her coordination, in various kinds of motion and in a fun manner. They will provide the sensory input that she needs to create new connections in her brain while adjusting the existing faulty connections so that she eventually will have the skills needed to be more independent. Her muscles will strengthen as she learns the motions of each device. Over time, as her strength and coordination increase, she will be able to move on her own and continue to have progress.

The zip line walking apparatus will provide Elysa a way to experience walking in a safe manner and minimal support. There is enough support to keep her from tipping over and falling, but not so much support that it limits her ability to move her limbs.

The optimal design is going to be based off Alternate Design 1, which allows for the most movement around the room. It consists of a zip line cable attached on either side of the room and a wheeled pipe that glides along the cables.

Figure 5.1: Optimal Design
We decided to do more research on an improved version of the track as we were worried that the pulley wheels might fall off the track if there were any sudden movements. After doing further research, we found a steel track system that could eliminate the need for the wheels and pipes and the need for extra pulleys. The current design for the zip line walking apparatus will be constructed from two steel roller track systems and a zip line, where a harness would be suspended from (Figure 1). Other than the change to the track and removal of pipes, the rest of the design remains relatively unchanged. The measurements for the device apply for the family room, as it is where the device will mainly be used in.

5.1 Components

5.1.1 Zip Line Track

The track component of the device is made up of several parts – steel roller track system, hanger with mounting plate, and end caps. A pair of the galvanized steel tracks will be mounted on two of the entryways, one on each wall, via the mounting plates that are attached to the tracks themselves. The tracks themselves are hollow tubes with an opening running the whole length of the tube, as seen in Figure 2. That opening is where the mounting plate will fit though and connects to the rest of the device. The tracks come in two different lengths – 8 and 10 feet and are $28.96 and $36.20 respectively. We decided to get the 10 foot track as it will give Elysa most space to move around, but we will adjust it accordingly if the client’s family prefers the shorter track.

Figure 5.2: Steel Roller Track System

We were also thinking about painting the tracks, which we could either be the same color as the walls, which would help the tracks blend in, or something colorful and cheerful to suit Elysa’s tastes. We could also keep them as is, but that all depends on what the client wants for that.

The wheels of the hanger are inside the track, rather than rolling on top of the cable. In the original version of Alternate Design 1, the zinc-plated steel pulley rolled on top of the cable. If for any reason Elysa were to move suddenly in any direction, there would be a risk of the
wheels falling off, since the wheels were not connected to the zip line cables. The enclosed track will prevent the wheels from falling off as they roll within the track. It only comes in one size and is $35.26 each.

5.1.2 attachment components for zip line

Two end caps, as seen in Figure 3, placed at the ends of the tracks will prevent the hangers from falling out when they hit the ends of the track, as well as keeping debris out. On each of the hanger’s mounting plates, one bolt-on tie down ring (Figure 5) will be screwed onto the plate with two size #14 screws and accompanying nuts to keep the rings in place. Initially, we were thinking of welding the ring directly to the mounting place as that would be a more secure attachment method. However, because the ring is made out of zinc-coated steel, it is different from the galvanized steel that the tracks are made of and cannot be welded together. The ring will give a place for a carabiner and zip line to attach to. There were various rings to choose from, but this one was found a cheap price ($1.75), and it provided a decent sized mounting plate for the screws.

5.1.3 Zip Line Cable

3/8” galvanized aircraft cable will be used in the zip line portion of the device (Figure 6). The cable is strong and flexible. It will span the width of the room (13’ ½”), but there will be around two feet of extra cable to allow it to be tied off. Steel cables are impossible to tie a traditional knot around. To accomplish this, cable clamps (Figure 7), also known as wire rope clips, are used to tie off the cable.
The cable is folded around a device called a thimble, as seen in Figure 8. These prevent the cable from crimping and protecting it from wearing at the anchor points. Once around the thimble, three cable clamps are clamped onto the cable. More than three cable clamps can be used to tie off cable. However, three clamps is the minimal amount of clips needed to tie of the cable. Usually three to four clamps are used in normal applications, but more can be used if there is an extra excess of cable. Figures 9 and 10 show how a finished tied off cable should look like.

To connect the zip line to the bolt-on tie down ring, a carabiner will used. Carabiners have many applications, but for this device, they provide the connection between the zip line, trolley/pulley, lanyard, and harness.
There are two different types of carabiners, locking (Figure 12) and non-locking (Figure 11). Figure 9 shows an example of a locking carabiner used to connect the zip line to the eye bolt. We are planning on using non-locking carabiners as they are cheaper than locking ones. Locking carabiners not necessary unless they are needed in applications where something could push against the latch, which would unhinge the carabiner. We might consider using the locking carabiner between the harness and straps so that Elysa cannot accidently unlock the carabiner if she were to accidently push the latch. For now, all of the carabiners that will be used will be non-locking, unless otherwise needed.

5.1.4 Swivel
A swivel is used to add a rotating dynamic when one is riding a zip line. In this case, we are using the swivel to allow Elysa to turn around and walk back in the direction that she just came from. The swivel can connect directly on the pulley, as to provide the connection for the carabiners and various attachments, shown in Figure 13.
5.1.6 Trolley

Zip line trolleys are used to glide a person down a zip line. The trolleys must have hardened steel sheaves to protect the trolley from wear and tear of cable riding. As this device uses a zip line and trolley in a more unusual fashion, the hardened steel sheath does not make a significant difference, if it even makes a difference at all.

![Petzl Tandem Speed Trolley](image)

**Figure 5.14: Petzl Tandem Speed Trolley**

All of the trolleys that we found that are specifically used for zip lining have a double-wheel design with ball bearings. This design is there to prevent the cable from twisting as the trolley rolls down the cable and provide minimal to no friction while doing so. There are various kinds of trolleys, ranging to ones with handles, ones that come with an integrated carabiner, and ones that have high speed capacities. Since we do not need any of the extra features, let alone extra speed capacity, we decided to go with the simplest and cheapest design we could find, which was around $80 (Figure 14).

5.1.7 Harness Structure

The harness structure will be a rectangle block of wood no larger than 16” x 6” x 1” (L x W x H). Initially, this block was going to be made out of Aluminum, but we were worried that it would be too heavy and bulky. Wood is lightweight, easy to obtain, and is cheap. It is also cheaper than plastic or metal and since it is merely a support connector between the harness and pulley, there is no need to buy an expensive plastic or metal.

We were also planning on painting the wood so it would match the rest of the structure. If we cannot find a good piece of wood for the block, plastic or medium-density fiberboard (MDF) can be a suitable alternative. On the top and bottom of the block, there will be three Aluminum u-bolts (Figure 15). The top three u-bolts will be connected to the lanyard and adjustable bungee cords, while the bottom three u-bolts will be connected to the straps that are connecting to the harness.
5.1.8 Harness

Elysa’s parents requested that we found a harness that would provide minimal support as they do not want her to have so much support that she is constrained to limited movement. They want her to be able to have just enough support to keep her upright and to allow for maximum movement. We were able to find padded harnesses that provided just enough support to allow for movement, as shown in Figure 16.

Similar harnesses have loops built into the shoulder and back straps, which are useful for attaching straps or bungee attachments to. However, as mention the zip line alternate designs, these kinds of harnesses are only made in adult sizes, which even though they are adjustable, they are too big to fit Elysa’s tiny frame, and are expensive. As a result, we are planning on buying a cheaper, similar looking in appearance and adding padding to it to make it comfortable enough for Elysa.

The harness that we plan on modifying is kids full body rock climbing harness (Figure 17), which is fully adjustable and also comes with leg padding. We would have to add padding to the shoulders, torso, and back, but at least there is one less part to pad. When we meet up with the client again after purchasing the harness, we will determine how much padding we
need to add and location of where we need to place it. Cloth will added to the padding to provide protection from wear over time.

5.1.9 Suspension

Lanyards, bungee cords, and straps will be used to connect the harness to the structure and to the pulley. Lanyards are most commonly used as a connection between the trolley and harness in zip lines. The lanyard (Figure 18) for this apparatus will connected in a similar fashion to how it is connected for zip line use. One end of the lanyard will connect to the trolley with a carabiner and the other end is connected to the harness at its tie in point.

![Image of Lanyard](image1.jpg)

**Figure 5.18: Lanyard Connected to Pulley via Carabiner and Tie Point in Harness**

The difference in this case is that the end with the carabiner will connect to the swivel (which is attached to the trolley) and the other end will be tied into the Aluminum u-bolts on the harness structure. The lanyard will be placed on the top middle u-bolt on the block, as it will take most of the weight of the rest of the structure. Two adjustable bungee cords (Figure 19), one on either side of the lanyard, will be attached to the other two top u-bolts at one end, and attached to the swivel carabiner at the other end. These two cords will be used because they will help keep the structure balanced. They also come with clips on either end, which reduces the number of carabiners that are needed for connections. Since the cords themselves are adjustable, they can be adjusted as needed.

![Image of Adjustable Bungee Cord](image2.jpg)

**Figure 5.19: Adjustable Bungee Cord**

![Image of Strap with Buckle](image3.jpg)

**Figure 5.20: Strap with Buckle**
To connect the harness to the u-bolts on the block, three 60” buckle straps (Figure 20) will be used. These will be connected to the harness via carabiners that are placed on the shoulders straps and on the back. The reason why we are using longer straps is that the longer straps allow room for adjustments as Elysa grows.

5.2 Realistic Constraints

There is going to be limits on the budget as a whole for two reasons: 1) our budget has to be divided among our several projects and 2) we can only ask for so much money so that all groups will be able to get money for their projects. Another constraint is with the harness. Ideally, we would hope to have enough money purchase one that is already padded, more durable, and safe than a cheaper harness. However, these more expensive harnesses are not an option because even if we have the money for one, the harnesses only come in adult sizes, which are too big for Elysa.

We plan on buying a more affordable harness that can be adjustable and made to be more comfortable. With the tracks, there is the option that we could buy additional tracks that can be installed on the rest of the first floor, but that is only if the family was willing to have more than one set of tracks installed in their house. However, if they wanted to have multiples tracks installed in their house, it is uncertain if we would even have the money to get more than 1 set of track.

This device is made to be used inside the client’s house, which would limit the usage to indoor settings. As the track needs to be installed in the walls, it limits the mobility of the track portion of the device as it can only be installed in one room at a time. While it can be removed and installed in a different room, as all of the rooms on the first floor are 13’ ½” wide, we were planning on keeping the tracks permanently installed in the family room since it would be a hassle to move the tracks into different rooms of the house. It is doable, but not practical. The family room in particular provides the most open space, which limits the chances of Elysa bumping into something.

As we are planning on Elysa to use the device for a long time, to maximize the amount of strength she gains from using the device, the materials used to make the device are important. Most of the materials are either for zip lining or made for industry, so they are all very strong and durable.

The device is designed specifically for Elysa. While all of the main parts of the zip line and track have capacities of over a few hundred pounds or more, it should not be used by adults. She should always have parent supervision, at least at first, until she can stand and walk around on her own without needing her parents’ assistance. Even though the track can be moved to different rooms on the first floor, as they are all the same width, it is not practical to move the tracks and could be dangerous if someone were to drop them. For the zip line and the
lower portion of the device, it can be brought outside, but it needs to be attached to a wall, pole, or tree to do so.

5.3 Safety

As the device will be mainly used indoor, corrosion should not be an issue. Since all of the steel components are galvanized, that will help protect the metal from corroding. The harness and all of the straps connecting to it and to the rest of the device need to be secure so she does not tip the structure over or slip out off the harness. As long as the straps for the harness are taut, the straps should not come undone from the u-bolts.