Optimal Design

Assisted Walking Device

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Project for Annalee Hughes
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**Introduction:**

The Assisted Walking Device has been designed to assist the client, Annalee Hughes, in learning to walk. Annalee suffers from cerebral palsy, causing irregular muscular movements which prevent her from walking. Primary issues include constant hypertension of the hamstring muscle, extreme adduction at the hip during leg swing, and exaggerated dorsiflexion in the feet when lifting off the ground. Her non-ambulatory condition limits her from reaching her full potential of independence. The device has been organized from the ground up to assure the client that every need as been sufficiently met. This will require active communication between the design team, the client, and her therapist. The designers will also meet with the client throughout the building process for consultation, measurements, and component testing.

The designers have chosen an optimal design for the product based on three alternative designs. These designs incorporated different leg securing mechanisms and different frame types. The most beneficial parts from each design were chosen after a meeting with the client and her physical therapist. Figure 1 and 2 displays the optimal design for the Assisted Walking Device. All components of the device were chosen based purely on optimal functionality. Figure 1 shows perspective images and Figure 2 shows the rear and side views of the completed design.
According to the client’s physical therapist, the most important component of the device is the leg restraints. Two of the designs required assistance for Annalee to equip the leg restraints, but they were rejected because the client should be able to equip the device as independently as possible. This is why the automatically clamping leg mechanism was chosen for the optimal leg restraint. Also, in previous designs, the frame and leg brace component were joined through the hip plate in a single, rigid structure. In response to stability concerns and gait research (see Hip Plate section), the designers decided to implement springs on the device which will connect the hip plate to the frame, thus giving both pieces some independence of motion. This will require the client to use her hip muscles to maintain balance, improving her strength and overall gait control.

Another main component of the device will be the brake controls. Annalee does not have a very strong grip, and is particularly weak in her left hand. To accommodate for this, the designers have decided to incorporate a brake handle that requires minimal force to apply tension to the brake cables. Also, the leg locking mechanism will be intertwined with the brake lines so the device will release her legs and remain stationary for mounting and dismounting. The device will feature adjustable parts to accommodate Annalee as she grows. Ideally the design will allow for collapsibility for travel purposes, but this is a secondary goal. All components will be described in full details below. All units shown in the technical illustrations are in inches.

**Subunits:**

**Frame:**

The frame of the Assisted Walking Device is extremely important since it is the structure from which all the necessary parts are attached. The most important feature of the frame is that it will allow rear entry by the client. This allows Annalee to get into and out of the device
with minimal, and eventually no assistance. The frame will be made of high strength aluminum, an ideal material because it is lightweight but strong. This will provide ample strength for any forces Annalee will apply to it. The frame will have a low center of gravity so that it is stable. To achieve this, lead may have to be supplemented to the bottom of the frame, and components attached higher up on the frame will be minimized in weight. The walker frame will be approximately 34 inches tall, not including the wheels, to properly support Annalee who is 56 inches tall. This will put the top of the walker at an appropriate height for Annalee to rest her elbows on the arm rests (see Arm Rest section). The legs of the frame will be adjustable a few inches to accommodate for growth, but stability is the primary concern. The frame will be approximately 30 inches wide on the interior. This will optimize the maneuverability and ease of entry of the device without sacrificing stability. Figure 3 shows a render of the Assisted Walking Device. Figure 4 shows a dimensioned illustration of the frame.

Figure 3. Frame of the Assisted Walking Device
Another important feature for the maneuverability of the frame is the wheels. There will be 4 wheels, as seen in the figures above. The wheels will be made of a hard rubber material, and will only rotate in the front two locations. Giving all four wheels rotation could cause them to turn in different directions, much like a shopping cart. This would require a force that Annalee is unable to exert to move again. The wheels will be 4 inches in diameter, larger than the standard wheels that come on a medical walker, to make the walker easy for Annalee to maneuver and negotiate over carpet and floor moldings. The hip plate will be connected to the bar running across the front of the device. This will be located approximately 30 inches off the ground which will accommodate for her current and future height.

The frame will provide the basic structure for the device, but it will be modified with several parts that will support Annalee and enable her to perform a proper walking technique. This requires the frame to be easily accessorized, a factor that depends on the diameter of the aluminum frame, and the available space to modify.

**Chest Plate:**

The chest component will be very similar to the hip plate. The chest plate will serve the purpose of giving the client a place to lean against while walking, increasing her stability. It is particularly important because she has very weak trunk muscles and tends to naturally fall forward, so she will need the extra support to keep her in a walking posture. Ideally, the chest plate will only be a temporary solution while the client initially adjusts to the device. As she becomes a better walker, she may be able to achieve a better upper body posture and will no longer need the chest plate.
Because the chest plate will be the highest part of the walker, and because tipping is a concern, it is critical that the plate be made from lightweight material. Since it will only support the top of her torso, head, and neck, the chest plate will not be required to bear a major load.

The structure will ideally be fabricated from a plastic, and an off-the-shelf component may also be suitable. If no plastic component can be produced, an aluminum mesh against an aluminum frame may also be a good candidate material. The bar connecting the chest piece to the device frame will be standard aluminum hollow bar stock. Figure 5 and 6 show the 3-D model and technical drawing of the chest plate.

Securing the client to the chest plate will be accomplished with a wide elastic strap, attached with Velcro. The client wants to be able to get into the device independently, but to mechanize an opening/closing mechanism may be out of the budgetary and technical restraints of the project. Therefore, the compromise reached is to mechanize the legs, which would substantially increase equipping time, while leaving the chest plate (as well as hip plate; see Hip Plate section) to be manually fastened by a helper. For details regarding the straps, see Chest and Hip Straps section.

Based on the client’s height of 56” and anthropometric data [1], the following dimensional estimates are currently proposed:

- Overall width of approximately 12 inches.
- Inner radius of approximately 10 inches.
- Outer radius of approximately 10.5 inches.
- Height of approximately 5 inches.
- Connecting bar length of 5 inches.

Figure 5. 3-D Model of the Chest Plate
Figure 6. Technical Drawing of the Chest Plate

**Arm Rests:**

Through input from the physical therapist as well as observations by the designers, it has been determined that the handle bars may need to be asymmetrical in their distance from the centerline of the walker. As described by the physical therapist, Annalee has more motor function in her right arm. The location of the right arm rest will have to be closer to her body. It will also have to be located further back in the design. Annalee’s left arm is not controlled as precisely, and therefore the arm rest must be located further from her body. Annalee was kind enough to perform some exercises with her physical therapist where she tried to lift her body from the seated position by applying force through her elbows. It was clear from this exercise that this motion is a realistic equipping action, but the handle bars need to be located under her chest, not under her shoulders. This is due to the forward lean in Annalee’s posture. Figure 7 and 8 are the render and technical illustrations of the arm rests, respectively.
Each arm rest will be mounted to a sliding bracket to allow for movement in the forward and backwards direction. The lateral movements will be accomplished with multiple locations of attachment. If the arm rest must be moved away from the body, it will easily be removed from the track and attached from another joint on the bottom of the rest. As seem in the arm rest figures, they will each be approximately 13-14 inches long, 4 inches wide and 1.5 inches thick.
The arm rests will be shaped in a U-shaped pattern. This is models after some of Annalee’s preexisting devices. The radius of the concavity of the padding will be approximately 3-4 inches. This will allow for her arms to be stabilized more efficiently and decrease the risk that she might slip off the rest. The designers have chosen to fabricate these arm rests out of a steel metal. The metal frame will then be coated with foam padding and then covered with a neoprene sleeve. The handle portion of the rests will be modeled after common bicycle handle bars. These handles will be angled to increase the comfort and look of the device. Although the handle bars and arm rest will not improve her ability to walk, they will increase her comfort and desire to use the device.

**Hip Plate:**

The hip component requires only a simple design, but biomechanically it is very important. Since the client must be able to directly equip the device from a sitting position, the hip plate will be open from the rear so she can pull herself in. A broad strap (described in the Chest and Hip Straps section) will secure her. The inner face will be moderately padded and covered in a soft neoprene or similar material. The structure itself will be fabricated from a thin, lightweight material. The most likely candidates include parallel aluminum bars, or aluminum mesh on an aluminum frame. Weight of the overall leg assembly (hip, legs, feet) is an important consideration because it will be supported from the frame by springs.

The reason for a flexible, spring-mounted design is based on gait and balance studies. In studies of muscle activation during balance perturbations, it has been shown that the hip is the primary source of balance recovery [5]. Although a rigid hip design would keep the client upright, it would not train her muscles to support and balance her body. The Hart Walker exhibits this limitation. Because its wearers are completely rigid in the device, their gait has a “gliding” characteristic, rather than exhibiting a natural bobbing motion [6]. As such, the Hart Walker can give its wearers mobility, but not independence. The Assisted Walking Device aims to remedy this issue by suspending the entire leg assembly from high-stiffness springs, which would provide good support but still require the client to exert small balancing motions in all three degrees. An additional advantage is that as the client improves softer springs can be switched in, providing her with a continual challenge. The springs will be attached to a bar around the perimeter of the hip plate.

Like the chest plate, the hip plate will be secured with a broad, elastic strap anchored with Velcro. See Chest Plate and Chest and Hip Strap sections for details.

Based on the client’s height of 56” and anthropometric data [1], the following dimensional estimates are currently proposed:

- Overall width of approximately 13 inches.
- Inner radius of approximately 6.725 inches.
- Outer radius of approximately 7.725 inches.
- Height of approximately 5 inches.
These dimensions are rough, and the project only requires a moderate degree of precision. Therefore, a successful design with modest manufacturing difficulty and low cost is very achievable. Figures 9 and 10 display the 3-D CAD model and the technical drawing of the hip plate.

Figure 9. 3-D Model of the Hip Plate

Figure 10. Technical Drawing of the Hip Plate
**Chest and Hip Straps:**

To secure the client into the device, there will be straps at the hip and chest plates. The straps will be made of high strength nylon and secure using Velcro. These straps are extremely important for Annalee’s posture while using the device, as well as her safety. The chest strap will keep her back straight and give her upper body support. The hip strap will need to be very tight because it will need to take load off of her legs in order for her to use her underdeveloped leg muscles properly. In order to meet these needs, the straps will be about 4 inches in width. These can be purchased to order very easily at material fabric stores or online. The straps will wrap around Annalee from one side of chest and hip plate to the other side, in a looping fashion. This is known as a hook up, loop down back strap. The straps are extremely important in providing support and safety, and thus must be fastened tightly with assistance from someone else. Eventually, as Annalee is more comfortable with the device and progresses with gait technique, she will be able to strap herself in more loosely. She is very limited with her left arm, and thus the loops will be positioned on the right side of the plates so that she can fasten them. Figure 11 shows the type of strap that will be used to harness Annalee into the device.

![Figure 11. Chests and Hip Straps](image)

**Calf and Thigh Restraints:**

The leg restraints will be the most intricate portion of the Assisted Walking Device. This component will be vital to correcting Annalee’s gait and providing the appropriate swing path when walking. They must provide enough support to resist her adductive force, while not cutting off circulation in her legs. The designers have developed a clamping design which will allow Annalee to independently mount the device and will provide enough force to stabilize her legs. Figure 12 and 13 show the clamping design of the leg braces. This design will be used for all four restraints.
The exterior leg bars will have three holes for different connect locations. These holes will be set up to allow for lengths between 11-13 inches for the thigh and calf support length.
As Annalee grows, these structures can be adjusted accordingly. When the leg restraints are in their closed position, their width will be approximately 3.5 inches. This should provide a tight enough support for Annalee’s legs. Each of the four exterior bars will be 0.25 inches thick by 1 inch wide. They will be fabricated to be 14 inches long, but will be adjustable as stated earlier. These dimensions are displayed on the technical drawing above.

The designers will manufacture the frames for the leg restraints out of steel with a high modulus of elasticity and high fatigue resistance. This will prevent deformation when forces are applied. The thigh restraints will be two inches wider than the calf restraints. This is due to larger forces being applied closer to the user’s hip joints. Each restraint will be design with two half frames that will be attached by a simple hinge. This hinge will allow the restraints to open when Annalee mounts the device. A torsion spring (figure 14) will provide the forces necessary to close the restraint around the user’s legs. Incorporated into the closing mechanism will be a lock. This will lock the restraints closed so Annalee’s legs will not slip out of place. As stated earlier, the restraints will be fabricated from high modulus steel with padding and a neoprene covering to provide comfort for the user.

![Figure 14: Torsion spring to provide legs with movement resistance and support](image)

Running along the side of the users legs will be steel rods. These rods will provide support to prevent Annalee from applying adductive forces. These rods will be attached to the hip plate and all of the leg restraints. Additional support will be added to the leg mechanism if testing show a need for it. The rods will have a joint located at the knee which will provide approximately fifteen degrees of rotation. Annalee’s knees are already bent at a ten degree angle. For normal gait, knee bending does not exceed fifteen degrees. The lower section of the leg rods will be attached to the ankle-foot orthosis. The above figures show the layout of the leg restraints, including the steel rods that run parallel with the user’s legs.

**Ankle-Foot Orthoses:**

Ankle-foot orthoses (AFOs) are a traditionally useful tool for correcting developmental gait problems. Therefore, the Assisted Walking Device will employ a modified open-backed AFO for two main reasons. First, the client has a sufficient level of gross leg mobility, but has difficulty consistent positioning her legs for each subsequent stride. An AFO mounted to the leg brace would keep her legs in a consistent striding pattern. Second, the client tends to internally rotate her legs as she swings them in a walking motion, but not when standing still. This is important, because she can equip an open-backed AFO from a stationary position with relatively little difficulty. Then, as she moves, the sides of the AFO would prevent the internal rotation of her legs.
There are several considerations that must be incorporated into the final AFO design. Notably, gait studies have shown that rigid AFOs can provide a high degree of stability, but change the timing and sequencing of muscles in balance recovery (cite). Therefore, while a rigid AFO would provide good support for the client, it is not compatible with the ultimate goal of training independent gait. A soft, moderately flexible design with a hinged ankle would provide adequate support while avoiding dependency of inappropriate muscle training.

The dimensions for the AFO were base on the client’s height. According to anthropometric data [1] and a height of 56”, the following estimates are currently proposed:

- Ankle brace height of approximately 6 inches.
- Foot length of approximately 8.5 inches.
- Foot height of approximately 2.2 inches
- Foot width of approximately 3.1 inches

Because of the soft material, these sizes do not need to be exact. A standard child-sized AFO should be adequate for the intended purposes. Dimensions will be formalized following a measurement session with the client prior to prototype construction. Figure 15 and 16 display the 3-D rendering and the technical illustration of the AFO.

Figure 15. 3-D Render of the AFO
**Padding for Restraints:**

All of the parts that Annalee will have direct contact with will need to be lined with a cushion, for both comfort and fit. These parts include the chest and hip plates, the handlebars, and the calf and thigh restraints. These will be lined with a thick-layer of Neoprene foam. This material is very durable, and also easy to clean because it is water resistant, so it can be wiped with water without damaging. All contact points lining will be 0.5 inches thick to provide enough comfort. This material can be attached to the necessary surfaces by a few different means, including using an adhesive, sewing, or clamping the edges between two plates that are screwed together. Neoprene foam is available in all large quantity and in all thicknesses for very reasonable prices [3]. Figure 17 shows the Neoprene material which will be used for the padding.
Figure 17. Neoprene Padding

**Brake Lines and Handles:**

In order to increase Annalee’s control over the device, simple brakes will be incorporated into the final design. These will be similar to bicycle brakes: levers, cables, and pads. Annalee has displayed good strength in her right hand. The designers will take this into consideration and locate all brake levers on the right side of the device. These levers will be located on the mounting handles near the rear of the device. The mounting handles will assist Annalee in lifting herself from the seated position when entering the device. This ability has been displayed to the designers and the rear entry feature was specified by the client. Figure 18 displays the mounting handle and the brake levers that will be located at the rear of the device. This location can be seen in Fig. 1 above.
An important feature in the mounting handle bars and brake lines is that they will be intertwined with the clamping leg restraints. Application of extra force via a simple power assist mechanism is under consideration, and may be incorporated depending on prototype trials. This extra force will open up the leg restraints and allow the Annalee to enter or dismount the device with less effort. Again, all braking controls will be mounted on the right of the device to accommodate for Annalee’s right hand dominance.

**Realistic Constraints:**

Teams building any walking training device for a patient with cerebral palsy will inevitably encounter several restrictions. The strength and abilities of patients with cerebral palsy vary drastically, and the device must be tailored to the limitations of the disease, but still challenge the patient to build muscle and balance. Devices that are currently on the market, such as the Hart Walker, are not ideal because they over compensate for the limitations individual cerebral palsy patients, and in doing so inhibit gait learning. The Assisted Walking Device will be based on Annalee’s abilities and manufacturing feasibility. This should decrease the number of restrictions on Annalee’s progression.

There are several constraints that must be addressed in the design and building process of the Assisted Walking Device. An off-the-shelf walker likely will be used as the base of the device, and parts will be added as necessary to meet the desired functions. This will save time, money, and issues with manufacturing a structure. However, problems do arise when modifying an existing walker for the specifications of this device. Firstly, an appropriately sized walker must be found. The walker must be small enough to maneuver through her house and an appropriate height that can support her weight (see Frame section). Also, the off-the-shelf walker comes with parts that will have to be removed as needed. Some walkers come with extra cages, brakes, and even a seat. The cage and seat would have to be removed, but the brakes could be modified to open and close the leg braces. On the other hand, taking parts off
of the walker will be much easier than adding new parts on. Some of the parts, such as the bike handle and armrests, can be purchased and only minor modifications will be necessary so that they attach securely to the frame of the device. Other parts will have to be fabricated from scratch. These will most likely include the clamping leg braces, hip stabilization brace, and the sternum brace. These cannot be purchased because there is little on the market that will meet the demands of the design. This slightly restricts the material that can be used and how it can be shaped, based on what the design team is capable of manufacturing.

For much of her young life, Annalee has been stuck in her power chair. This has made it hard for her to reach her potential as an active young girl. Due to travel restraints, particularly fitting into a car, the design should be designed with portability in mind. Ideally, it will be transported easily to her grandparents’ house or anywhere else she will be. This requires the device to be made of a lightweight material that does not sacrifice strength and durability. It must also be as compact as possible, a feature that will help in its maneuverability, without sacrificing its stability.

Providing a device that is safe to get into, walk around in, and get out of is the most important aspect of this design project. This also creates several complications and limitations for the device. The patient must be able enter the device from the rear, in a sitting position, either from a chair/couch or her powerchair which is significantly raised from the ground. This provides difficulty in terms of where the hand supports will be placed and how high the device must be to remain stable and allow her to support herself while she is equipping it while preventing tipping. Also, the brake lever for the clamps on the leg device must be adjusted so that the patient can apply sufficient force to open the leg clamps. Once in the device, it is important that there is no way for the device to tip over. It must be extremely stable with a low center of gravity, and must support her so that if she loses balance it will not be so rigid that it will tip. This will require a hip brace with some give in it, so a spring-suspended design will help absorb any sudden change in force.

The greatest limitation considered in the design of this device is the lack of muscular strength of the patient. She will require assistance to load and unload from the device until she develops appropriate muscles for lifting and supporting her body. However, it is the goal of the Assisted Walking Device that she be able to move around once she is in it. This requires the device to be light and roll smoothly enough so that the patient may push it as she walks. By forcing Annalee to use her muscles, the device will be improving her physical health and functionality. Several aspects of the device will assist in this as much as possible, making it easy to move and ideally allow the patient to walk unassisted and improve her freedom.

The device will have little environmental footprint, so constraints in that respect are minor. The client has not expressed a need for any motors; therefore, there will not be any exhaust or battery usage. All padding in the device will be removable to increase the cleanliness of the device. As stated above, the device will be manufactured from on the market products with little alterations needed. This makes the device extremely manufacturable since the team will not need extensive manufacturing capabilities.
Safety Issues:

The device has been designed to incorporate all safety issues expressed by the client and the physical therapist. There were a few issues that were discussed pertaining to Annalee’s abilities and strength. Obviously, balance will be a major issue that must be addressed since Annalee does not have any prevention reactions. This physical imitation creates many of the safety issues that the design team has factored into the device.

As stated above, one major issue for the design team was the balance of the device. The client has expressed the need for the device to be mounted from the seated position in her power chair. This means that she will be pulling on the device from a high point of balance. In order to counteract this force, the device must have a low center of gravity. This low center of gravity will prevent the device from tipping onto Annalee, as well as assist in the overall balance of the device while in use. In order to create the low balance point, counterweights may be used. The actual need for counterweights and the amount necessary will be determined once testing has begun.

Another way the design has addressed the issue of balance was to implement springs at locations attached to the hip brace. A rigid structure will tip over much easier, therefore, have some play in the hip brace will take some of the forces off of the frame and assist in the overall balance of the device. The designers and the physical therapist have discussed this safety issue, and have agreed that this would be the best solution. After doing some research into posture, the design team understands that recovery from a large disturbance of balance is initiated at the hips. This is why the hip brace must have some play and allow for some movement.

The frame of the device must be able to carry the load of Annalee’s body and not crumble under pressure. All joints in the device must be strong and the metals used to manufacture the device must not warp or bend after use. To keep Annalee safe, the straps must be strong enough so they do not separate when her weight is applied. The design team has chosen Velcro as the material which will harness her chest and hips in place. The Velcro must be strong enough to prevent her from slipping down the device. The chance that her throat could get pressed against the chest plate if she slips down the device would be addressed by the strength of the Velcro.

All safety issues have been discussed with the client and every action will be taken to limit the opportunities for accidents occurring. The designers understand that accidents can still happen if the device is not used properly and will attempt to forecast any misusage.

Impact of Engineering Solution:

The transition from childhood to adulthood is a transition to independence. As a child grows older, more and more skills are learned that contribute to overall self-sufficiency. For many physically disabled children, this process is skewed because they may be mentally and emotionally ready to do greater things, but are limited in their mobility. Our client, Annalee Hughes, is very bright and has many different hobbies. Her cerebral palsy severely limits the
activities she can perform, but given the correct practice and equipment, her life has great room to grow.

This is why the Assisted Walking Device is such an important project. It is not a toy or a convenience item, but instead it fills a hole in the market that can genuinely improve the lives of disabled children. The client’s physical therapist has expressed the concern that the devices on the market simply do not provide the training to teach a child to walk. If the client can learn to walk even modest distances, such as from the living room to the bathroom, her quality of life could be greatly improved.

Economically, this device could likely be brought to market at a lower price point than existing walkers. However, this is difficult to ascertain since there is very little overhead in an academic environment. These types of devices have low production numbers, so economics may dictate a higher price in a marketplace situation. Since the current estimated cost is approximately $1000-1700USD, there are some important global implications of the device. First, the Assisted Walking Device is very simple and easy to maintain, and could be manufactured overseas as a substantial cost savings. Second, in many third-world countries, disabled members of the population are hidden away and have little chance to join the greater society. They certainly do not have access to public support systems or physical therapists. For example, in China the quality and availability of devices such as walkers, wheelchairs, and braces is very poor due to lasting societal stigmas. If the Assisted Walking Device were manufactured at a low cost, perhaps well under $1000USD either in the United States of overseas, it may provide an important lifestyle enabler for people with disabilities around the world.

Ultimately, however, large-scale ambitions remain firmly speculative. The bottom line is that the client, her parents, and her physical trainer have an important need to fulfill which is not satisfied by the current marketplace. They have tried several devices with varying degrees of success. If the project is successful, the Assisted Walking Device will improve her life in a tangible, lasting way.

**Life-Long Learning:**

*Design Techniques*

We will learn a great deal from the design process. Determining the client’s needs and expectations will help us understand the needs of disabled children and the challenges they face in daily life. Building and refining the CAD model will be an extensive process involving constant communication with the client and gait research, as well as learning to utilize advanced Autodesk Inventor features such as force analysis. A virtual model of the client will be developed for this purpose, so biomechanical and anthropometrical skills will also be learned. Gait research and consultation with the client’s physical therapist will not only provide a scientific basis for the Assisted Walking Device, but will give us important background knowledge on gait development and pathology.
In addition, a major technique learned will simply be the art of planning and coordinating groups. Microsoft Visio will be used to produce flow charts and diagrams for easy planning. We will need to learn Microsoft Project in order to keep track of project goals and deadlines. Substantial coordination will be required between our team and the client, as well as within our team. All of these skills will be important regardless of each team member's final career or educational path.

**Manufacturing Techniques and Materials**

The manufacturing goal for the Assisted Walking Device is to produce a product that achieves all goals using the simplest manufacturing techniques possible. Although the deliverable to the client will be a customized prototype with no plans of future production, manufacturing and materials must be selected with small scale commercial-type production in mind.

As such, we will explore techniques in modifying off-the-shelf components. For the chest and hip plates, we will learn to bend metal bars and attach mesh or similar material in order to create a lightweight, yet supportive structure. Although using an off-the-shelf walker frame would be ideal, we may need to also learn to fabricate larger pieces of bent metal for a customized frame if standard models are found to be unsuitable. The AFO would be a difficult device to manufacture with our capabilities, so we will learn to the features of standard AFOs and select one based on the client's needs.

Although the current design does not require use of the PIC16 microcontroller, the microcontroller may become a valuable resource that we will need to understand and apply if automation is required. It will be particularly important because the client has limited strength but can operate buttons well. Therefore, C programming skills and circuit development may become an integral part of the project in the future.

The most important skill learned during the manufacturing phase will likely be the process of revision. We will need to develop highly adjustable parts that, through repeated trials with the client, can be adjusted to build an ergonomic final product.

**References:**


