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Cerebral Palsy Inclusive Play & Mobility

By Mai Nguyen

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by

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Abstract

According to the Centers for Disease Control and Prevention one to four children out of a thousand are born with a certain type of Cerebral Palsy in the world, with eighty percent of Cerebral Palsy cases are spastic. Play and social engagement with the development of children is important and, in many cases, hard for children with Cerebral Palsy. Most adaptive solutions for children with disabilities focus on the fundamentals of everyday life. Children with disabilities need to be socially interactive so they do not feel isolated. Wheelchairs, standers, and adaptive tools are continuing to be developed. The topic of this thesis will focus on socially interactive development of children ages five to nine. How may we improve inclusive play for children with Cerebral Palsy? Giving children the tools to participate as a group for activities will help them socially, physically, and confidently develop. Researching the existing practices for the development of children with disabilities and using information gained from interviews will effectively generate a better understanding of ergonomics, and full-bodied human interaction designs.

Keywords: Development, Fundamentals, Interactive

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Lincoln, Enzo, and Murphy! I did it!

I hope I made you all proud.

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Chapter 1 – Introduction

This chapter discusses how Cerebral Palsy children interact with others, as well as their difficulties and needs. To further improve their comprehension in a variety of situations.

1.1 Problem Definition

Developmentally children prosper with group play. Children with special needs are more likely to be socially isolated. The problem definition that is being addressed is

the value of the environment for children to engage in group play. This problem is important at a micro level as it is catering to children with disabilities. However, there is or potential for any child to use for group play. This problem definition meets the thesis criteria by enhancing the lives of children with disabilities. It has the greatest potential for full-bodied interaction design that will allow the children to play in a group. It will be a product that will take all the ergonomics and human factors designed to fit all children of various sizes and shapes.

1.1.1 Problem Finding

To address the topic purposefully and correctly, independent research will be conducted to gain a better understanding of children with Cerebral Palsy. Various tools will be utilized through the process of research, user observation, surveys and meetings will be important to develop an unbiased and objective information. Continuing to gather and further understand the importance of Play Therapy for children with Cerebral Palsy. There are many groups on Facebook that offer some insight to the daily life of families with children that have Cerebral Palsy. Reaching out to these groups and other educational centers will be very informative. The research sources that have been explored and will continue to be beneficial are the CDC, Cerebral Palsy Education sites, advisor(s), Conductive Education Centre, and Ontario Federation for Cerebral Palsy. These sources will be contacted/found with/on one-on-one phone calls, videos, surveys, peer reviewed journals, scheduled meetings, and scheduled phone calls with contacted centers.

1.1.2 Problem Framing

It is more difficult for the children to have the opportunity to interact with other children, let alone other disabled children. This topic was chosen for a family member

that has Cerebral Palsy. His condition is more severe and has a hard time interacting. He is well loved and has everything provided for him. It is a goal to try and provide a better quality of life for him to enjoy playing.

1.1.3 Needs Statement

This section has compiled some preliminary statements from the information that will contribute to the organization of the related necessities for the users. These statements are gathered from the observations and interviews of the primary and secondary users.

- Child needs to *have* social interaction because it *helps* with mental development
- Child needs to *be* independence because it will *give* them confidence
- Child needs to *be able to* play because it *is the basis* of learning
- Parent/child needs to *feel* stability because they will *want to be safe* during new tasks
- Parent/child needs to *be able to* trust the process because the child *will learn* on their own

1.1.4 Expert Interviews / Surveys

There was a survey conducted to reach a broad setting for a wide range of participants. Interviews that will be performed mostly in the beginning of the project and periodically throughout the whole process as more questions will arise.

1.2 Rationale & Significance

Children need to be social to develop interactive and social behaviours. According to the Center of Disease Control, 1 - 4 children out of 1000 are born with Cerebral Palsy. Children with Cerebral Palsy are more isolated. While there are many

different types of Cerebral Palsy, the focus is more on children from ages 6-9 with Spastic Diplegia (dy-PLEE-juh). It is a type of paralysis to which legs are usually the affected limbs of people with Cerebral Palsy.

1.2.1 Key Information to be Determined

The most important aspect of the topic is to provide a better quality of play for children with Cerebral Palsy. Social development is vital to the growth of a child. Making group play enjoyable and simple for everyone to enjoy. By assisting the children in play, it could help parents and medical staff while interacting with the children. There is much potential for this topic to accomplish bringing together different children and developing socially while having fun.

1.2.2 Key Questions to be Answered

To appropriately gather information specific questions were asked to gain insight on the topic. As the research progresses there will be more questions that will arise. Some of the questions for the survey are listed below.

What is your relation to the child?

Can you describe the type of Cerebral Palsy the child in your life has?

What kind of games do you play with the child?

What are some limitations/problems with the current games?

Do you believe that Play Therapy is beneficial? Why or why not?

Can you give some suggestions to help further understand the area?

1.2.3 Investigated Approach Planned

Understanding the products that are on the market and how they are used will provide greater insight on what works. During user observations we will gather pertinent

information that will contribute to the design of the prototype. This will give the benefits and drawbacks that the various primary and secondary users will experience.

1.3 Background / History / Social Context

This section delves into the topics that will broaden the scope of the trends that will influence users. It will look at the history of each topic as well as different trends that will interact with the user, product, and environment.

1.3.1 Demographic Trends

The demographic for the children we are looking at the vast majority of time spent as a child with Cerebral Palsy is in a doctor or specialists office or therapy session. Many children are not able to socially interact with others, the use of their limbs is not the sane as others. During the research there is more focus on children with little to no use of their legs, commonly known as Spastic Diplegia (Proctor et al., 2021).

1.3.2 Lifestyle Trends

Children with Cerebral Palsy spend much of their time with specialists, school, and their parents. There are many different sessions with the specialist, doctors, and therapists that are spent individually. The use of mobility aids and adaptive products vary within each location. While school is where children without Cerebral Palsy get the most social interaction, children with Cerebral Palsy have a different experience. Without sufficient care staff at most schools, the ratio of teachers to students with Cerebral Palsy vary. Some children do have individual teachers that are provided; however, this depends on funding. Children with Cerebral Palsy get can have a varying social life, depending on the family dynamics.

1.3.3 Media Trends

Throughout the study, the topic received very little media attention. The products featured depict children who are either very high functioning or very low functioning. Few advertisements for items explain how they are used, and even fewer show proper ways of how to get in and out of them.

1.3.4 Product Trends

There are numerous things available for children who require assistance. The children will constantly require assistance to get into and out of the gadgets because they are extremely complicated and require a lot of attention from the parent or specialist. The structural integrity is critical for the children's safety when utilising these devices.

Chapter 2 – Research

This chapter will go through the data that was initially obtained as well as the various approaches that were used. It will concentrate on user research and product benchmarking in order to further the design process's full-bodied human integration.

2.1 User Research

By evaluating photographs, videos, and user interviews, the data obtained in this chapter will provide an in-depth look at the various users (into tiers). Product benchmarking will be used to assess the benefits and shortcomings of present products in order to get as much information as possible about consumers and products.

2.1.1 User Profile

The various user groups will be broken down to primary and secondary users. Most subjects will have a combination of primary, secondary, and tertiary users. However, through our research, the main users only fall into the primary and secondary which will be further explained in this section.

Primary / Secondary	**Secondary**	**Tertiary**
Parent Child	Pediatricians Physical therapists Speech pathologists Teacher Development behaviouralists	Other children Other adults

Table 1 Users

2.1.2 Current User Practice

The current user practices use wheelchairs, adaptive tricycle, scooter / standers, stair glides / elevator / lifts, adaptive vehicles, communication devices, adaptive art supplies, toilet / bath chairs, writing tools, and Theratogs. Many of these products are large and bulky, making it harder for the user to use while playing with other children. These devices are mainly used during various therapies, which also limits how well children can use them to interact socially. Below there were two different personas curated to better understand the users with the information gathered through the research, interviews, and surveys.

Figure 1 Photo of child

Persona 1: Trent Smith

Age 7

Occupation Student

He enjoys family time, spending time with friends at school and playing soccer (even if he doesn't get to play it often).

Figure 2 Photo of mother

Persona 2: Maribelle Smith

Age 31

Occupation Bookkeeper

She works full time and is the main caregiver to her son with Cerebral Palsy. She does all the housework, cooking and chauffeuring her son to his various doctor's / specialist appointments and therapy sessions.

Maribelle is a single mother that lives for her son. She wants everyone to treat him with respect and not feel sorry for him because he has a disability. She has fulltime remote employment to ensure that she can provide for all his needs. She is definitely a busy mother. Trent has a big loving family that is always attentive to his needs. Although he is unable to walk or sit up on his own, Trent is always a part of the conversation even with his limited communication skills. He loves to play with his cousins and enjoys watching movies with them.

2.1.3 User Observation – Empathy & Activity Mapping

This section will further the knowledge of understanding to the user's mindset during the use of the current products on the market. Figure 1 is an empathy map for a boy with Cerebral Palsy. Figure 2 is an empathy map for a parent of a child with Cerebral Palsy. These charts allow further insight on the mindset of these primary and secondary users. There will give a better understanding of how to empathize with each persona on their own. Allowing in depth knowledge for each persona.

Figure 3 Empathy map for Child

1. WHO are we empathizing with?
- Parents of son with Cerebral Palsy (7)
- Family members

2. What do they need to DO?
- Learn non verbal cues to identify what child needs/wants
- Responsible to see various doctors/specialist appointments
- Initiate playdates for children

3. What do they SEE?
- Child growing fast but less developmentally
- Happy playful child, eager to be entertained/participate
- Family wants to help/doesn't know how

PAINS
- Parent could feel isolated/lonely
- Worries for child in so many different aspects; playing with other children, learning, health etc.
- Unable to provide basic developmental teachings without help of specialist

GAINS
- Gives child independence
- Gives parents a break
- Social interactions for the children to grow and helps with their social development

5. What do they SAY?
- "These things are so heavy and bulky"
- "Why is everything so expensive?"
- "He's not a baby, his development is just at a different pace."

4. What do they DO?
- Worry for child
- Takes child to many different appointments
- Teach, play, feed, bathe, etc. the child

THOUGHTS and FEELINGS:
- Constant worry if she is providing the best care for child
- Scared to think about child's future, if they even have one
- Unconditional love for child
- Anxiety for the child's well being

6. What do they HEAR?
- "He's just a baby"
- "Its ok, he will do at his own pace"

Figure 4 Empathy Map for Parent

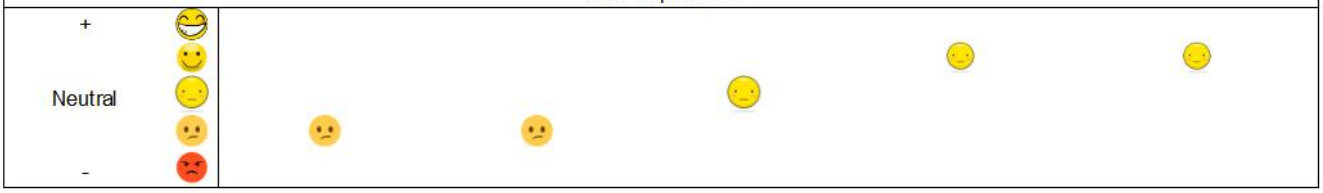
	Before	Before	Set up	Task 1	Task 2
User Goals	Practice	Practice	Apply TheraTog	Stand	Walk
User Actions	Child stands	Child walks,	Dress child in TheraTogs	Child Stands	Child walks
	Child has a **hard time standing**, **not stable**, has **uncontrollable motions**	Child has a **hard time standing**, **not stable**, has **uncontrollable motions**	Gettting the straps and fabric around the child to correct comfort and fitting	Child is able to stand by self with more stability and control	Child takes steps with more stability and limited assistance
		Taking uneven steps, crossing legs			
User Thoughts			Its a little difficult to get this on	Oh I can stand up without anyone helping	I can control my body!
Storyboard/photos					
User Experience					
+ / Neutral / -					

Figure 5 Journey Map of Child Using TheraTogs

The video that was observed had a child with Cerebral Palsy who was unable to balance or walk on his own. With the assistance of the physical therapist and the

TheraTogs, the child can walk comfortably and balanced. Figure 3 shows the process of the child before and after he puts on the Theratogs suit. It is the journey of him trying to walk on his own with only the assistance of his physical therapist, to trying on the Theratogs, the TheraTogs helping him be more balanced, and walking with minimal assistance from the physical therapist. This suit can be worn under the clothes to give strengthen specific muscles. The suit does not offer the stability for the child to walk and play on his own.

2.1.4 User Observation – Human Factors of Existing Products

During the observation, the child had assistance to wear the product. The wearable TheraTogs suit has interchangeable straps that allow the child to grow with the fabric. The various products that have been benchmarked in sections below; all need the assistance of another person. The mobility aids on the market are bulky and may not even fit through a standard door. The robust size contributes to the balance of the product ensuring it will not tip over during the use.

The survey results, some participants mention play products. These products need to be accessible for the children using them. The height of the product is very important for the child to be able to reach in order to have a full experience while in use to play. The height of a product is important to develop certain skills, such as grasping and gripping. Also, to maintain the safety of a product in use, the height needs to be taken into consideration to not overextend a child.

2.1.5 User Observation – Safety and Health of Existing Products

During the video observation, the TheraTogs suit tightly wrapped the child. The straps were strategically placed so support the child’s weaker muscles and restrict other

muscles that have involuntary movements. The suit would still require the child to have assistance while in use as there is no protection for the child if they fall. The suit could greatly improve the practice of mobility during physical therapy sessions with professional or adult supervision. The light fabric for of the suit would not affect the gait of the child. It is best used to correct the posture which relieves the strain of the unvoluntary movements of the child.

Mobility aids on the market are built to safely protect the child from falls as they move, regardless of their enormous stature and appearance.

2.2 Product Research

This section will provide a better understanding of the existing products on the market and how their benefits and drawbacks will affect the current and future users. The research is based on the various interviews and survey results.

2.2.1 Benchmarking – Benefits and Features of Existing Products

The table below lists the current products found during research and investigation, it is a compilation of the benefits and key features of the different products.

 	1. Adaptive tricycle • Moderate to severe children may not be able to ride without assistance 2. Scooter/standers • Sometimes require assistance to get in/out • Allows child to stand without assistance and be more independent

  	3. Stair glides/elevator/lifts • Opens space for child to move about 4. Communication devices • Confidence building 5. Toilet/bath chairs • Requires assistance Allows child to more comfortably be in the tub or on the toilet

Table 2 Benefits and features of existing products

						
1	2	3	4	5	6	7
Wheelchair	Communication Devices		Adaptive Art Supplies			
Zippie Iris	Tecla-E	PDF Print outs	Pencil Grip Pinch Grips	EasyHold Silicone Grip	Glifo	Theratogs
Benefits						
Promotes independence Confidence building Empowers child Light weight Mobility for the immobile Easy for cargivers to assist Grows with child	Promotes independence Confidence building Empowers child Light weight Multiple Device control Tech Friendly Grows with child	Promotes independence Confidence building Empowers child Light weight Low tech	Promotes independence Confidence building Empowers child Light weight Control Comfort	Promotes independence Confidence building Empowers child Light weight Control Comfort	Promotes independenc Confidence building Empowers child Light weight Control Comfort	Promotes independence Confidence building Empowers child Light weight Improves postural movement issues

Table 3 Benefits of existing products

According to the advisor, these products do resolve certain issues however, there are different aspects of the user's everyday life that has been left uncovered. These benefits give the user more independence.

2.2.2 Benchmarking – Functionality of Existing Products

The products can be divided into two main categories: assistive transportation or adaptive tools. The transportation devices are used with assistance for every product. The adaptive tools allow the child to be more independent while working independently or during use while bathing or using the facilities. As stated in the table below the devices function in different ways.

1. Communication devices Allows child to communicate without speaking	4. Adaptive vehicles Specially modified vehicles to transport child
2. Scooter/Stander Child can stand without assistance	5. Stair glides/Elevator/Lifts Child can reach different levels
3. Adaptive Tricycle Exercise and fresh air	6. Toilet/Bath chairs Extra comfort for child Stability for parent

Table 4 Functionality of existing products

2.2.3 Benchmarking – Aesthetics and Schematic Profile of Existing Products

For the purposes of expanding on the aesthetics of these products, there will be more emphasis on the transportation devices. Each device has its own different functionality however share a similar aesthetic as they are all bulky and industrial. They have a very industrial machine or structured look. They can be conveyed as intimidating and very uninviting to other children and adults. The bulkiness of the products ensures stability for the child's movements. Each product possesses multiple different ranges of sizes to maximize their usage for the children, and to justify the costs.

2.2.4 Benchmarking – Materials and Manufacturing of Existing Products

The basic main frame of these products consists of either an aluminum or steel frame. Aluminum is considered to be the lighter of the two materials (Weight savings-steel vs. aluminum, 1994). The frames are bulky and make it difficult for the caretakers to load and unload or store. There are many walkers and wheelchairs in the market that

are switching to an aluminum frame because they are considerably lighter than their competitors with the steel frames. Many of the main components to these frames are welded together. There is use of nuts and bolts to provide easier replacements to other parts. The main adjustable features consist of the spring button.

2.2.5 Benchmarking – Benefits and Features of Existing Products

The existing walkers and wheelchairs have greatly evolved. The use of lighter materials and strong joints will provide optimum structural support. The spring button will change the size in standardized increments. Current products offer wide ranges of extra features and addon’s for additional costs. The interchangeable features or addon’s available are multiple cushions for the seat and body, seats, headrests, footrests, armrests, backrests, built in scales, gait trackers, backpacks or pouches, canopy, torso straps, belts, tray, spoke guard, anti-tip, colours, and much more. The features allow the child to find the best fit for a product they will use almost daily. The addon’s boost the usefulness and practicality of the product.

2.3 Summary of Chapter 2

Through all the research of the user observations and product bench marking it is apparent that there are difficulties that these users face with each product. Limitations on what a child can do independently during a group setting.

Chapter 3 – Analysis

This chapter will provide an association between the user observations and the product bench markings to systematically examine the data. Allowing the child with Cerebral Palsy to independently play with other children will improve their overall development. There will be more insight on the current user's and products.

3.1 Analysis – Needs

A growing child needs to have social interaction to help with development. The social interactions will require the child to be more independent to create confidence while playing. Play is one of the bases of learning. As the children grow stability for both parent and child are important to undergo new tasks. Trusting products and the process will aid the parent and child to learn on their own.

3.1.1 Needs/Benefits Not Met by Current Products

With the current market, the entirely bulky and robust mobility aid products are visually lacking. It is difficult to interact with others properly when the child is using the products. The large structures can feel intimidating during group play or settings. It decreases the likelihood that other children to be willing to approach. They need to reduce the size and drastically improve the aesthetics.

3.1.2 Latent Needs

For a user to use a product that will transport or become mobile, the primary user's need to be comfortable. Addition to comfort, feeling fully supported while using a device for the child is very important for the child to have confidence during use. Having

a certain level of stability and to be aware of how to use the product. To be and feel completely safe during the process will contribute to the ease of use for the user.

3.1.3 Categorization of Needs

To better understand the benefits, there are various needs that the user will or will not know that they have. The user has certain immediate needs which have become more apparent as they need it to be easier to use for the child and parent. For more convenient transport with a smaller or more compactable product. The overall cost of many of these products is an issue. Similar to the laten needs, the user needs to feel safe, comfortable, and stable during use of the products. The sense of control for the user will promote confidence during use.

The user will always want to be happy while using a product. With confidence the user can have fun and excitement independently and especially during group play.

Figure 6 shows the full Categorization of needs table as expanded above.

Immediate Needs	Latent Needs	Wants/Wishes
Easier	Needs to feel supported for safety	Happiness
Convenient	Stability	Fun
Cost	Comfortable	Excitement
Durable		Group play
Safe, comfortable, stable		
Control		

Figure 6 Categorization of Needs

3.2 Analysis – Useability

The usability of a product is how a person is using a product and if they can use it effectively. Without the understanding of needs mentioned in the previous section, there will be a lack the fundamentals of a great product. Going through the journey mapping and user experience in this section will provide a better understanding of the usability for the product.

3.2.1 Journey Mapping

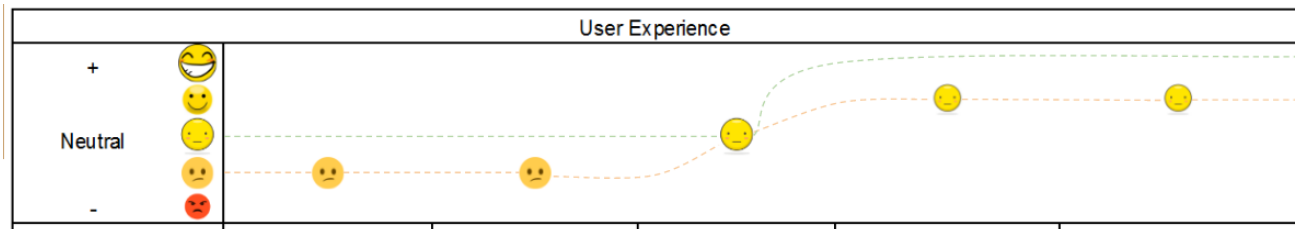
	Before	Before	Set up	Task 1	Task 2
User Goals	Practice	Practice	Apply TheraTog	Stand	Walk
User Actions	Child stands	Child walks,	Dress child in TheraTogs	Child Stands	Child walks
	Child has a **hard time standing**, **not stable**, has **uncontrollable motions**	Child has a **hard time standing**, **not stable**, has **uncontrollable motions**	Gettting the straps and fabric around the child to correct comfort and fitting	Child is able to stand by self with more stability and control	Child takes steps with more stability and limited assistance
		Taking uneven steps, crossing legs			
User Thoughts			Its a little difficult to get this on	Oh I can stand up without anyone helping	I can control my body!
Storyboard/photos					
User Experience					
+   Neutral   - 	    				

Figure 7 Journey Map of Theratogs in Use

The journey map above provides insight on the previously mentioned video user observation. It allows a better understanding of how the child feels before and during the use of the TheraTogs. Some pains the child may experience is the lack of independence while using the product. The child wants to be independent however, even putting on the TheraTogs requires assistance of another person. The added stability and balance are a very beneficial use of the product. While the child may feel

more stable than when not wearing the TheraTogs, the product will not fully support the child which will require a hand for assistance.

3.2.2 User Experience



User Goals	Practice	Practice	Apply TheraTog	Stand	Walk
Problems/Challenges	child is unable to do things independantly	Child is unable to do things independantly	Requires assistance	Child is standing and still requires assistance	Child walks but still needs assistance incase
Ideas/Take-aways	A group setting would be different	Assistance is almost always required	Great for therapy	Would it work in group play?	Light weight materials

Figure 8 User Experience Map

The User Experience Map above begins to explore the user experience with the pink line. It shows how unhappy the child is without any type of assisted mobility device on. The child is unhappy as he is attempting stand on his own, his spastic movements don't allow him to stand still or upright on his own. The same movements of his muscle spasms when he is trying to walk. His expressions become neutral as the TheraTogs are being fitted to his body in anticipation for what happens when he wears the device. He becomes happy as he experiences standing and walking with the stability and the support of the TheraTogs.

The green line in Figure 8 shows the targeted user experience. The emotions that the user could be experiencing while using a product. The ability to design a product that immediately creates a sense of happiness or elated feelings is what the product will strive for. To allow the user to comfortably participate in group play. For the user to interact unassisted, with confidence.

3.3 Analysis – Human Factors

The contents of this section will explore the process of research on the mock up of an exoskeleton product. This insight will provide more knowledge of what will work for children with Cerebral Palsy to be able to play more inclusively. There will be a wide range of measurements provided to have a better understanding of the user and product. As well as what will work and what still needs to be further refined.

3.3.1 Product Schematic – Configuration Diagram

The product schematic of the proposed design will show what parts are required and approximately where they will be located. These components will affect how the body will interact with the product, if the ergonomics is correct, how the product will function, and the overall aesthetics to the final product.

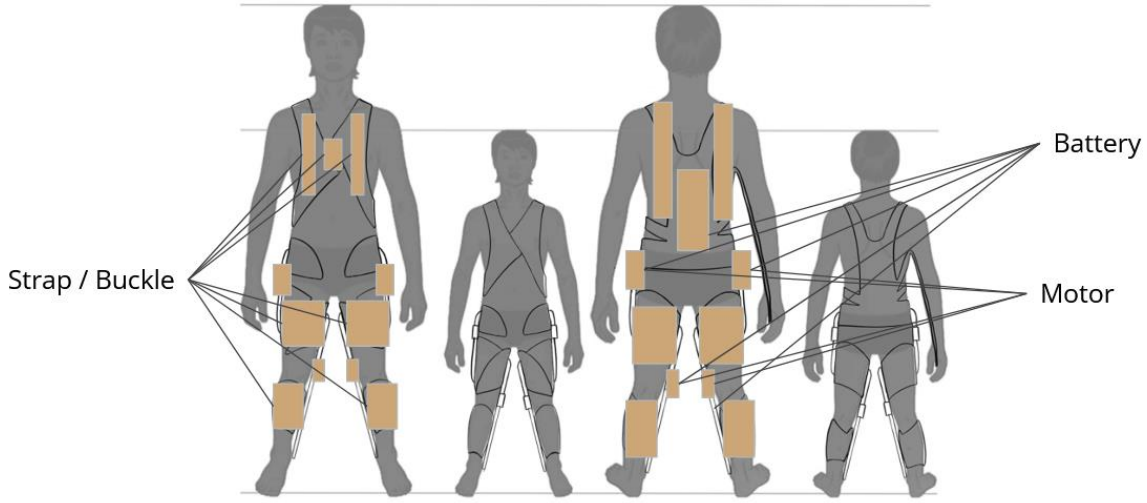


Figure 9 Configuration Diagram

The configuration diagram depicts two different heights, the taller boy to be the 95th percentile 9-year-old boy and shorter boy to be the 5th percentile 6-year-old boy. On the left the diagram points to places on the design that would be an adjustable strap or

buckle to expand or contract to the child. The location of the various batteries will assist with how the product moves with specific locations for the motors as well.

3.3.2 Ergonomic – 1:1 Human Scale Study

Introduction

This study will go through the process of research on the mock-up of an exoskeleton product to gain more knowledge of what will work for children with Cerebral Palsy to be able to play more inclusively. It will go in depth on the many different measurements of what is needed for the product, an understanding of the product and user, and what works or needs to be further researched.

Literature Review

The ergonomic analysis will explore the prototype that will give a better understanding for the stature of the boys or girls. Creating an ergonomic 1:1 representation of the prototype will allow a better understanding of a child. Using data, the Center of Disease Control (CDC) provided about the stature and weight of the children, the appropriate measurements for product. The design will take into consideration what features will be required and how to incorporate the growth of the child into the design.

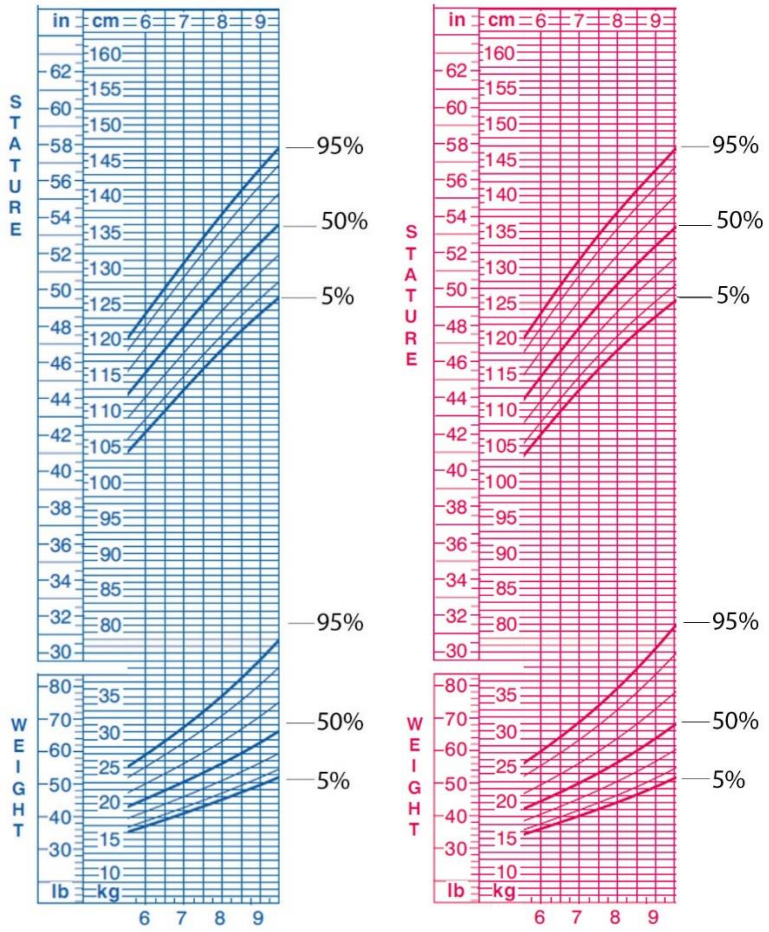


Figure 10 Growth Charts from Center of Disease Control

The growth charts from the Center of Disease Control above shows the different percentiles of girls and boys between the ages of six to nine. With the information provided, the difference between the boys and girls stature and weight is very minimal between these ages. Comparing the stature, the biggest difference between genders is one to two centimeters shown in Figure 11.

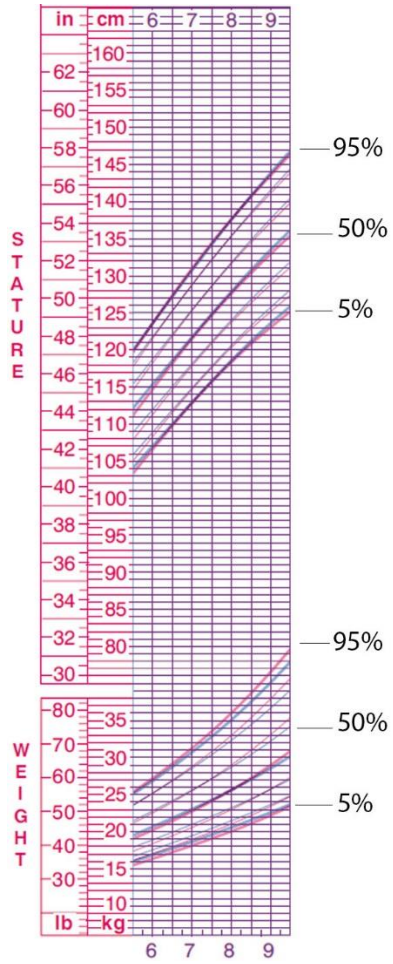


Figure 11 Overlapping Comparison of Girls and Boys Charts

The references displayed above display cover the main stature height of the children from fifth to ninety-fifth percentile. This information will allow the child to be comfortable while using the product, grow as the child grows in any rate with minimal technical adjustments. The factors taken into consideration will allow the product to be used in an efficient manner while maintaining the safety of the child while in use. Understanding where the weaknesses to strengthen and secure the product.

Figure 9 shows the 95th percentile nine-year-old boy, standing at 144 cm and 5th percentile six-year-old boy, standing at 107 cm. (*Growth Charts - Clinical Growth Charts*, n.d.)

Methodology

Building the mock-up in 1:1 scale will provide more knowledge to understand the ergonomics and human factors of the child during use. Using paper to create the mock-up will provide a fast way to closely measure and transfer to the final material. Cardboard was used as the final mock-up material. The ridged nature of the material will be useful for the product to hold its shape.

Figure 12 1:1 Mockup

Figure 12 shows the child in the full mock-up of the exoskeleton. It ensured the child was able to fit in the smallest form of the product. The vest, hip, thigh, and calf of the product will extend with growth. The extension will be with Velcro to allow comfortable growth and tight fitting. Each part will fit tightly for the smaller children and can be loosened. Figure 13 shows the overall height at the smallest configuration of the product.

Figure 13 1:1 Mock-up

Analysis

The mock-up was created around a 10th – 12th percentile seven-year-old boy. He stands at 115cm and weighs 18kg. The photos above are the bottom portion of the product. This would be at the smallest size for the product. The inner thigh to the bottom of the foot measures from 46 cm and will extend up to 76 cm. The max height of this product will accommodate a child that is up to 148 cm tall. (*Growth Charts - Clinical Growth Charts*, n.d.)

The thigh and calf grips will allow for the child to expand and contract to comfortably fit every size child. The torso area will house the main battery pack on the back. The straps are extendable to accommodate growth as well. Each of the joints will have a motor and a battery to power it. The back of the torso will hold a reserve battery to connect and extend the time of use for the product.

Limitations and Conclusions

Although the product is quite customizable, and the product lifetime will only span if the child's stature is within those limitations. The joints worked well although there were no motors installed. They bent and allowed the user to walk and move naturally. The overall fit of the product allowed the 10^{th}-12^{th} percentile child to walk and move comfortably.

3.4 Aesthetic and Semantic Profile

An exoskeleton walk will allow a child with Cerebral Palsy to gain confidence in everyday tasks that most take for granted. Giving the child the power to walk on their own could manifest emotions and strengths they did not know they had. Hence the superhero aesthetic will provide a fun and confidence building product.

Figure 14 Aesthetic and Semantic

Adapting features from current superheroes will give the design more appeal to a child in need of a confidence boost.

3.5 Sustainability – Safety, Health, and Environment

Taking into consideration all the materials used, each manufacturing process was considered before including each component.

The rigidity of the stainless steel, carbon fibre, and polycarbonate will provide a sturdy frame that will keep the child in a safe position to walk and stand. The torso has a rigid support built into the vest that will help hold the child's back up right, in a better walking position. Ludere will be required to be calibrated to each child before the initial use.

The materials are non-toxic and will provide a comfortable fit for each child. Ludere will be custom fit for each child to use and grow into. The added comfort of the polyethylene foam thickness will be adjusted to the child's comfort level. With the child being able to interact and play with others, it will help the mental and physical development.

The textile actuators are a purposeful material that would not require new machinery or materials other than the coating of the electroactive polymers. However, the polymer will replace the dye in the process. To reduce the new machinery required it will reduce the manufacturing carbon footprint of this product.

According to the C2C Certified Products Registry, there is a product in the polyethylene foam family called ThermaSmart PRO. It has all the requirements to be a sustainable product, however, it does not mention if the product is nontoxic or has the ability to be used for wearable products. The standard polyethylene foam is not certified, it still is quite sustainable due to the fact that it is 100% recyclable (INTCO Recycling,

n.d.). Although not every recycling plant has the ability to undertake the product. There are some that will accept it to be recycled if mailed in (Fully, n.d.).

Carbon fibre reinforced polymers are recyclable. The cost of it however, may vary depending on the location of such plants (Shehab et al, 2021). The process that has been developed by using a Fluidized bed is the most energy efficient way to recycle the material, however the results are not ideal for all that want to reuse the material (Butenegro et al, 2021). The various recycling methods will produce a different result (Butenegro et al, 2021). It will depend on which result is needed to select the process in which to recycle the material (Butenegro et al, 2021).

3.6 Innovation Opportunity

Although there are many different devices that are offered to the children, the focus of most existing items caters to one function and being practical. These features are admirable, however, cause the items to be practical, big, and bulky. The current products requiring constant assistance from the caretaker / parent while in use.

Designing a product that allows the child to participate in group activities while still maintaining their independence and style. This will allow the child to seamlessly join their cohorts in various activities including inclusive play.

3.6.1 Needs Analysis Diagram

Based on data collected for to understand the challenges that the user, product, and environment of use has been tabulated into the following.

	User	Product	Environment
1	Family (primary/secondary) - Communication within family can help positively - Wanting to help but not always around to know routines and typical behavioural	Wheelchair - manual/automatic - Bulky - Expensive	Functions Home Playgrounds school
2	Physical therapist - Advancing over time - Only able to help during sessions.	Adaptive tricycle - Expensive - Moderate to severe children may not be able to ride without assistance	Gym Office School
3	Child (primary/secondary)	Scooter/standers - Bulky - Intimidating - Sometimes require assistance to get in/out - Allows child to stand without assistance and be more independent	Playground Home Gym Office School Functions
4	Pediatrician (secondary)	Stair glides/elevator/lifts - Only available where installed - Needs assistance to use	Office Home
5	Specialist (primary/secondary)	Adaptive vehicles - For parents to transport children to and from appointments - Must be a specialized vehicle	Office Home
6	Speech therapist (secondary)	Communication devices - Useful for children to communicate without words - Confidence building	Office Home
7	Therapist (secondary)	Adaptive art supplies - Allows all children to participate - Empowers child with independence	Office Home
8	Parent (primary/secondary)	Toilet/bath chairs - Requires assistance - Bulky	Playground Home Gym Office School Functions

9	Teacher (primary/secondary)	Writing tools - Only for children able to use hands	School
10	Developmental Behavioural Specialists (primary/secondary)	Theratogs - Allows children to stand with minimal help - Adds stability to stance	Office Home

Table 5 User, Product, Environment

3.6.2 Desirability, Feasibility & Viability

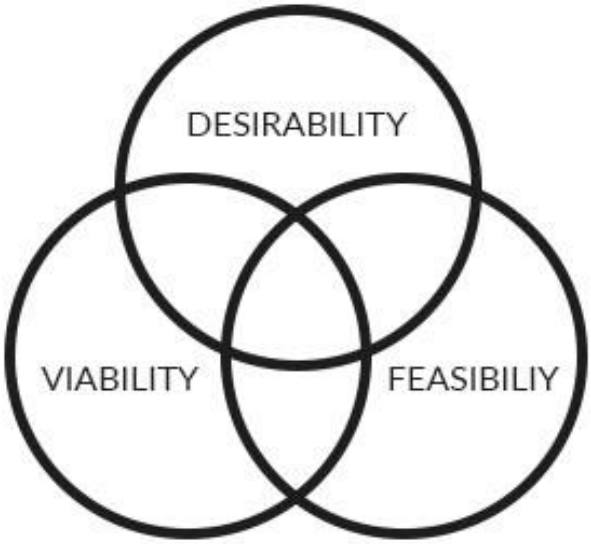


Figure 15 Desirability, Viability, Feasability

Desirability

The desirability of the user pertains to the user experience. To enable the child to use for long periods of time. The child should be comfortable to grow with the product. The separate batteries allow the suit to be used while one battery is charging. Intermingling with adults or children during play and / or social gatherings.

Viability

The current product benchmarking revealed that the current mobility solutions for children with Cerebral Palsy are big, bulky, and very expensive. The robust features of these products pose an unapproachable look that is intimidating for other children. The industrial features of the products make the structures feel very cold, unattractive and uninviting to use or look at.

Feasibility

The combination of a ridged exoskeleton set of legs with the textile actuator torso reduces the weight of the product. An adjustable component to the suit will allow the child to wear the suit while they grow. The adjustable straps around the torso, thigh, and legs ensure a wide range of body sizes can use the product. This reduces the need for a parent or guardian to purchase additional different mobility aids as the child grows.

3.7 Summary of Chapter 3 – Defining the Design Brief

A design brief helps to focus on a clear approach for mitigating the challenges that the user will encounter with present products. This design brief will give you a clearer idea of what objectives you'll need to meet in order to give the product a singular strategy. Children must interact in order to learn and develop during play, both independently and inclusively.

A wearable designed to help children with Cerebral Palsy socialize in a group environment.

1. Improved comfort and ease of use for child during play
2. Mitigates the appearance of independence while in use
3. Streamline the robust look and feel to reduce intimidation for other children during play
4. Streamline how it can grow with the child
5. Strength and durability
6. Incorporating new technology to ensure the product is up to date
7. Easily adjustable to improve the ergonomic fit for all users
8. Mitigate the process to wear and remove the product
9. Improve the aesthetic of the product to have a fun aspect
10. Strong, sustainable materials are used to ensure that the product has a long-life cycle.

Chapter 4 – Design Development

This chapter will go into the stages of Ludere's design and how it came to be. It will cover over concept research, concept strategy, concept refinement and validation, concept realization, design resolution, and physical and CAD model development.\

4.1 Initial Idea Generation

Various sorts of research, surveys, and interviews were used at the start of the project. The ideas were then compiled into the following set of priorities.

Goals	Benefits	Needs	Wants
• Compact product • Easily portable • Not intimidating	• Easily obtained • Cost effective • Fun	• Supportive • Safe • Lightweight	• Affordable • Compact

4.1.1 Aesthetics Approach & Semantic Profile

To determine the design direction, take into account inspiration from numerous search engines such as Pinterest. The ridged structure that has been applied is explored in the aesthetics of the mood board illustrated in Figure 16. The internal mechanics of Ludere's design were aided by the skeleton elements. The superhero aesthetic was used to help point the design in a direction that would appeal to the children to be strong, couragous, and fun.

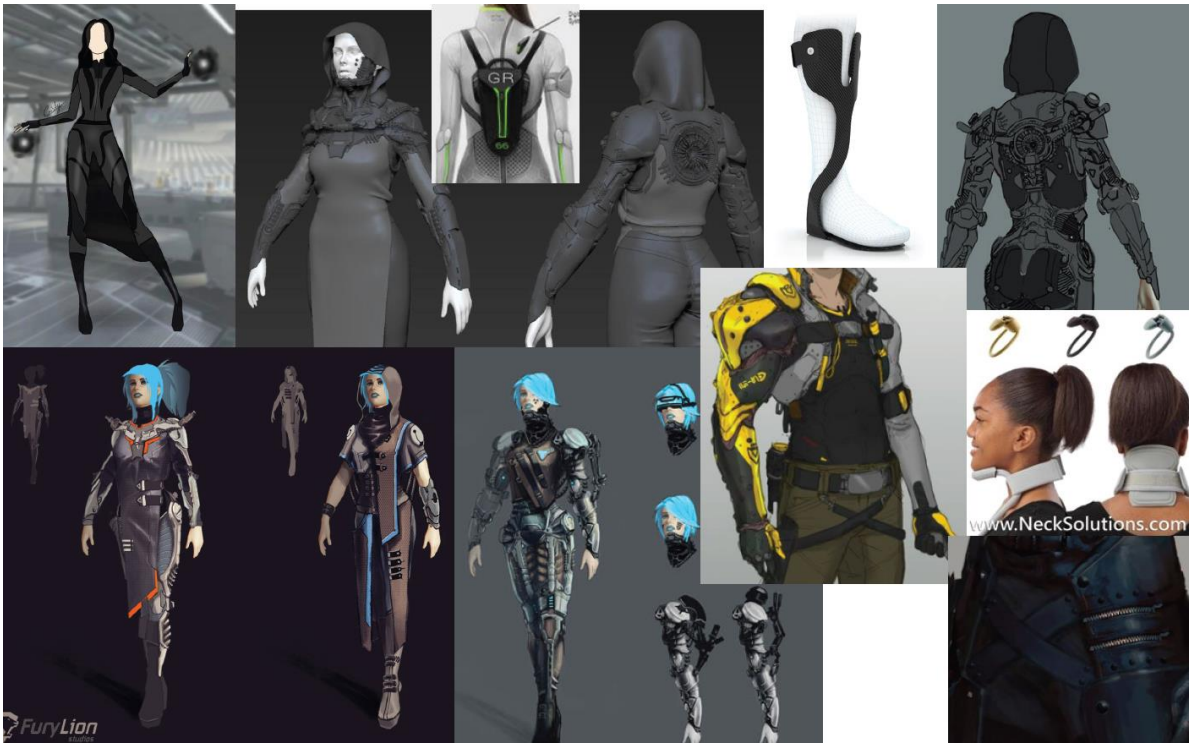


Figure 16 Aesthetics Inspiration

Figure 17 Avengers

4.1.2 Mind Mapping

The beginning of the design process, there was a mind map developed to gain a better understanding of the various problems and allow the initial designs to reduce the traditional designs and utilitarian aesthetics. The mind map contributed the focus of the design to ensure the goals, wants, needs, benefits, and pains were all taken into consideration.

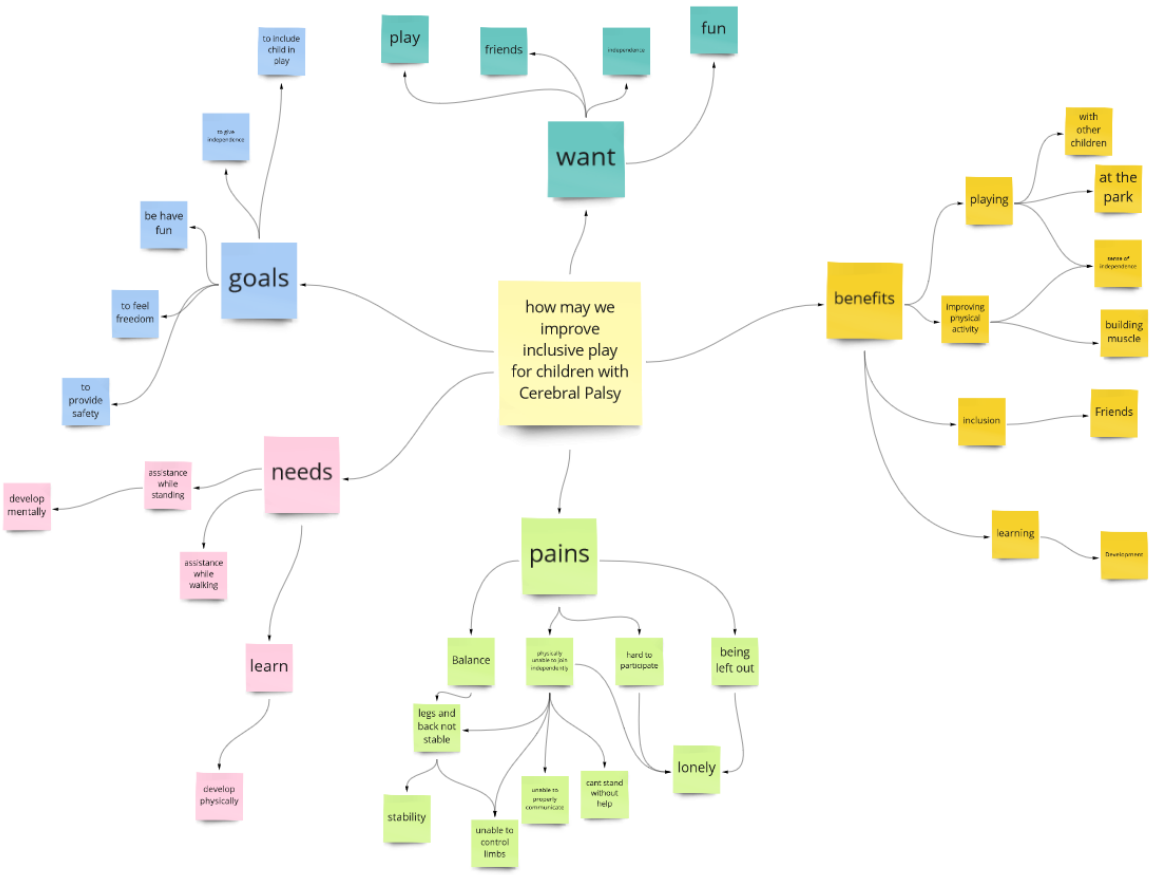


Figure 18 Mind Map

4.1.3 Ideation Sketches

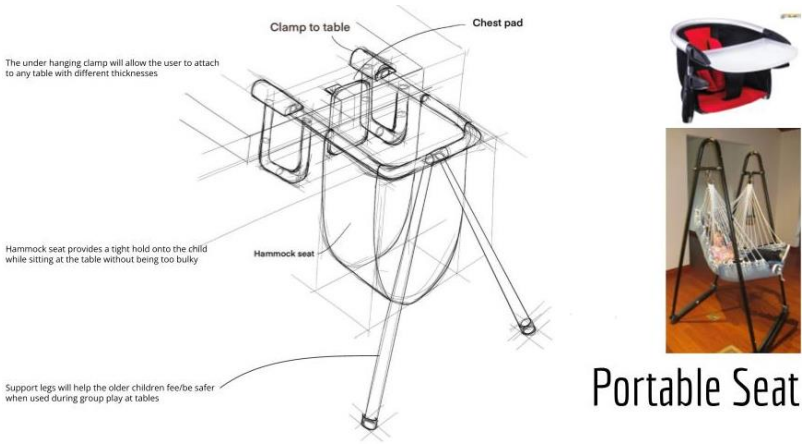


Figure 19 Ideation

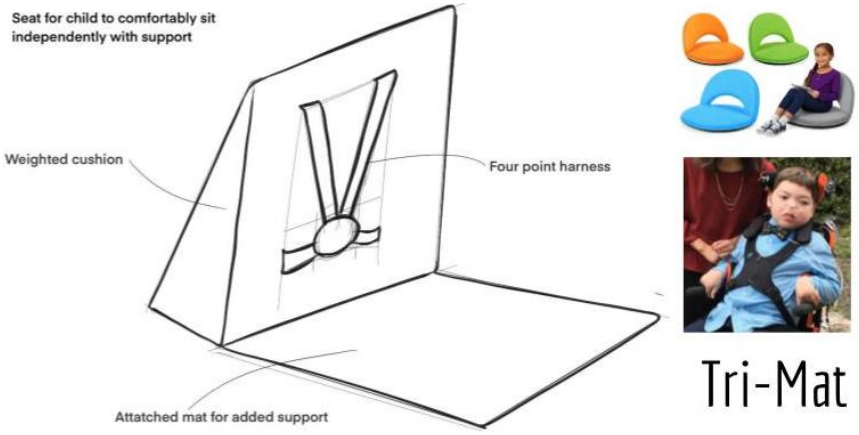


Figure 20 Ideation

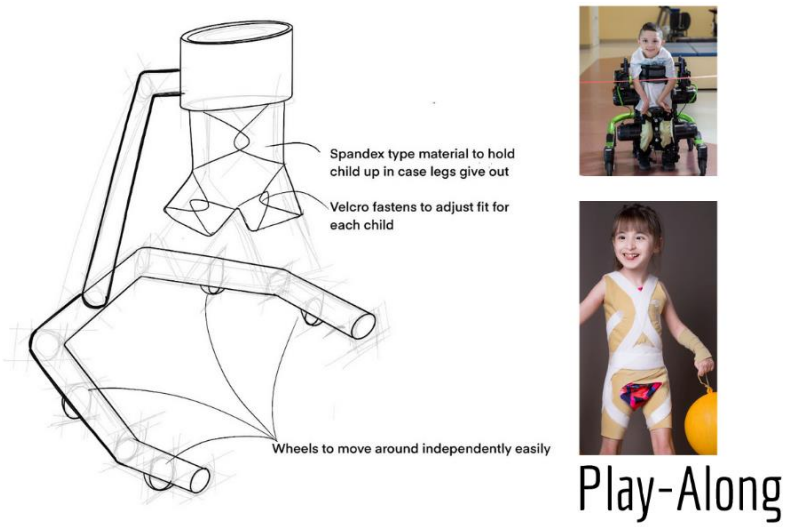


Figure 21 Ideation

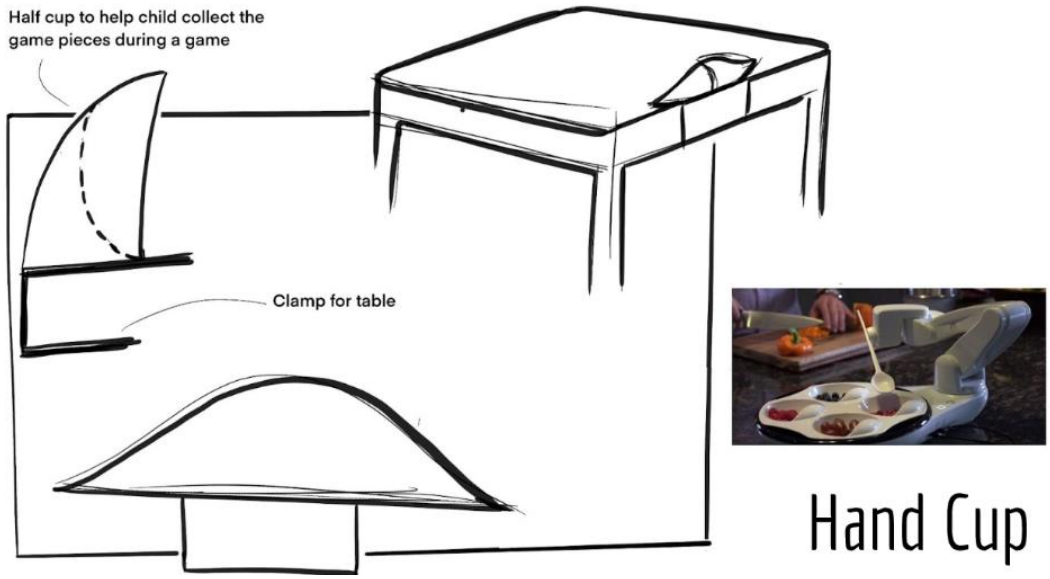


Figure 22 Ideation

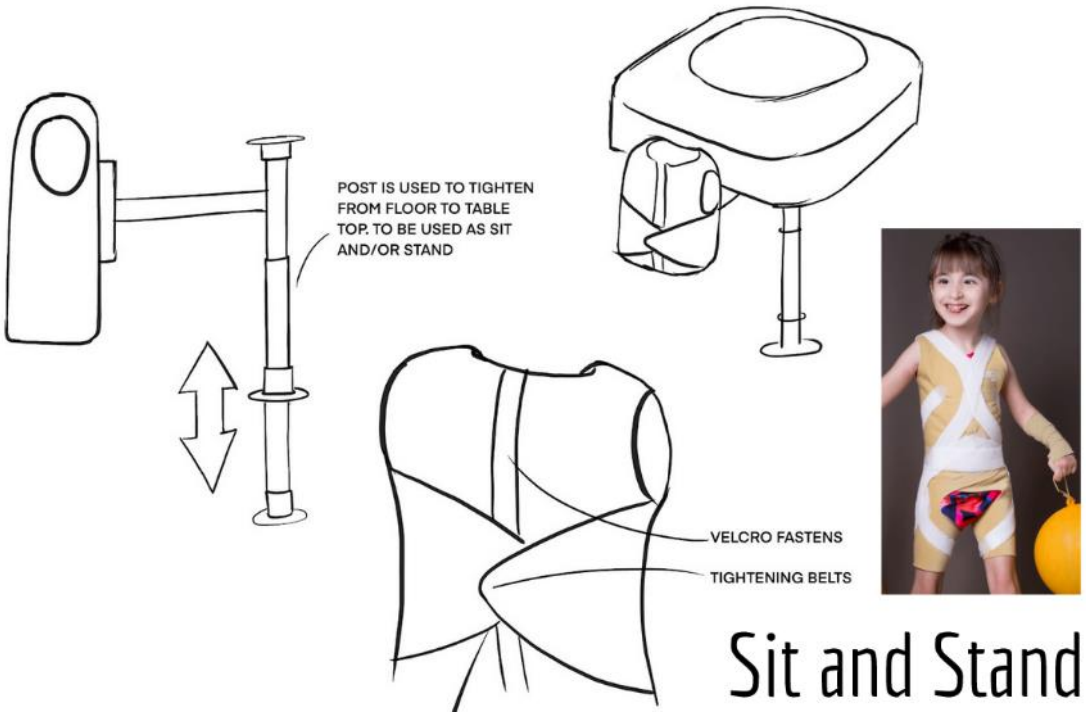


Figure 23 Ideation

4.2 Concepts Exploration

The following subsections will exlore a combination of initial concepts that had the most promise and innovation. These would be the exoskeleton suit that would help the child with a full bodied experience. This could safely and aesthetically allow the child to be mobile and independent. There would be a need for assistance for the child to get into the suit.

4.2.1 Concept One

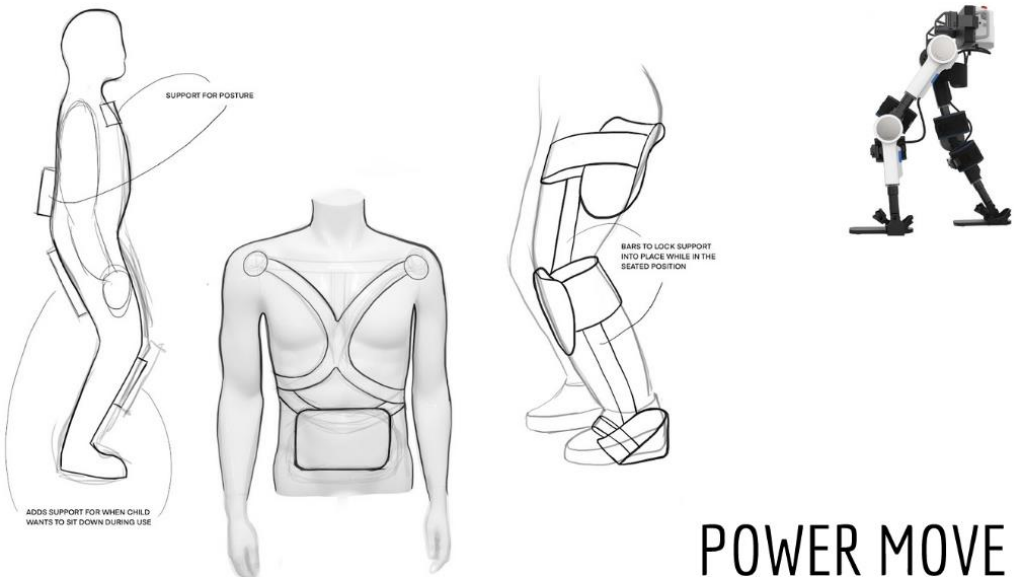


Figure 24 Concept

4.2.2 Concept Two

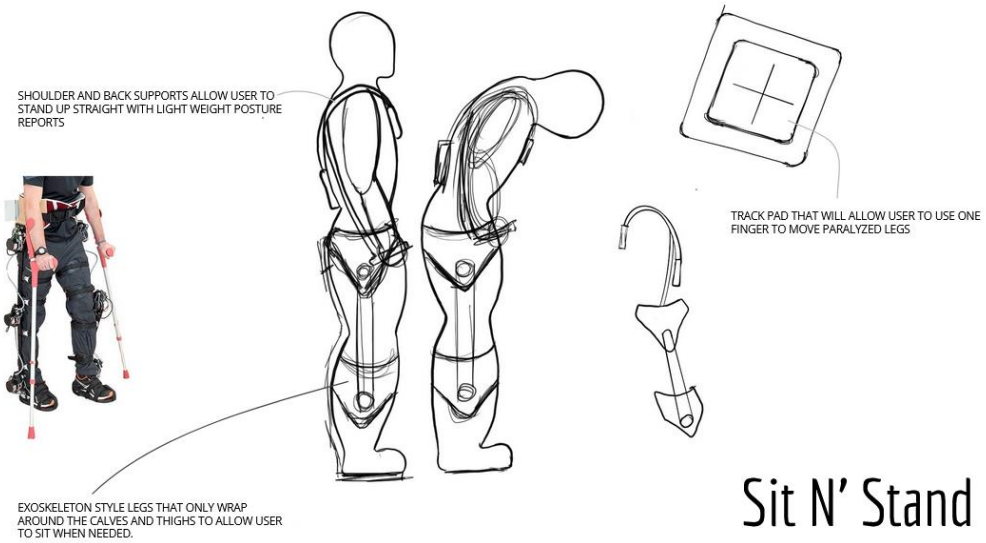


Figure 25 Concept

4.3 Concept Strategy

The features needed to construct an exoskeleton are being narrowed down. A torso wearable that will help the child stand up straight by supporting specific muscles. Specific supports are used by the skeletal framework that will hold the legs. The key muscles utilized to sit, and stand will be securely supported with these supports. Each of these unique supports will be utilised to ensure that the youngster remains balanced and stable while utilising the product.

4.3.1 Concept Direction & Product Schematic

The initial ergonomic study of the 1:1 scale mockup verified the specific support points of the exoskeleton. The main supports required are the adjustable straps and buckles. These are strategically placed on the body to support the specific muscles. The front and back torso, hips, back of the thighs, and front of the calves. The multiple batteries and motors were placed in various parts of the exoskeleton to evenly spread out the weight.

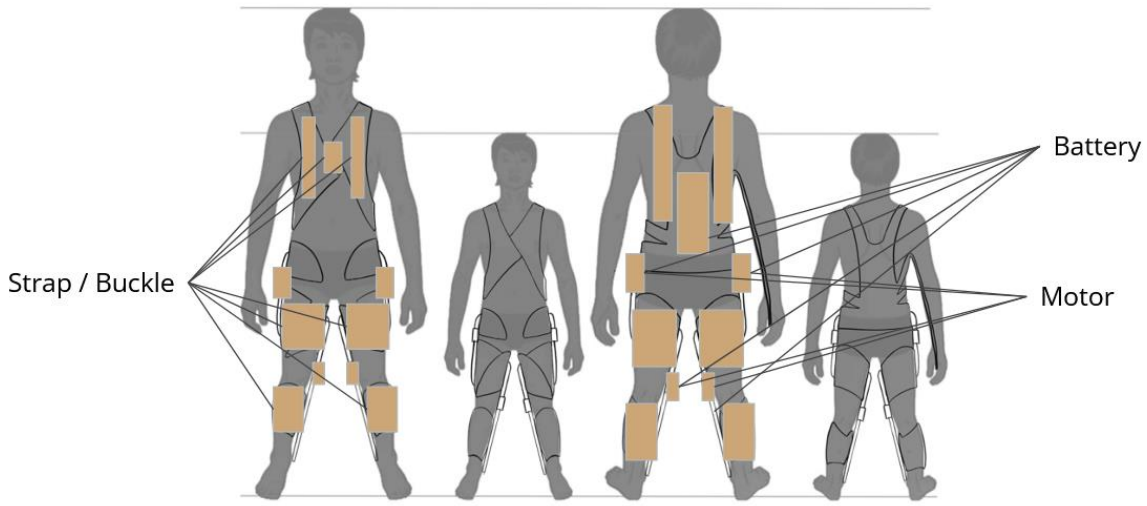


Figure 26 Schematic

4.4 Concept Refinement & Validation

4.4.1 Design Refinement

The aesthetic of the legs and torso were explored in many differet directions. Utilizing the various moodboards and photos to ensure the design was unique and futuristic, while maintaining the specific required features. The final concept refined and resulted in the figures below.

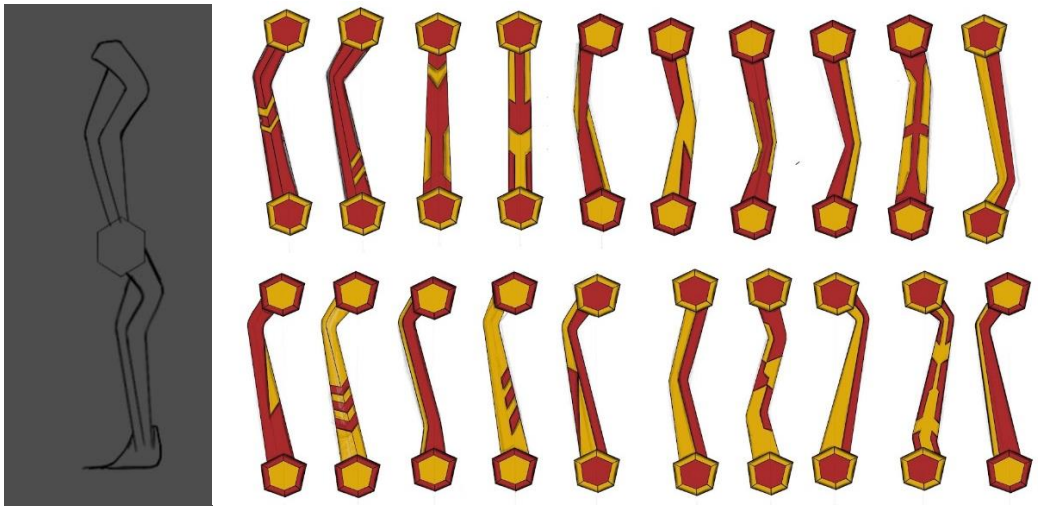


Figure 27 Sketch

4.4.2 Detail Development

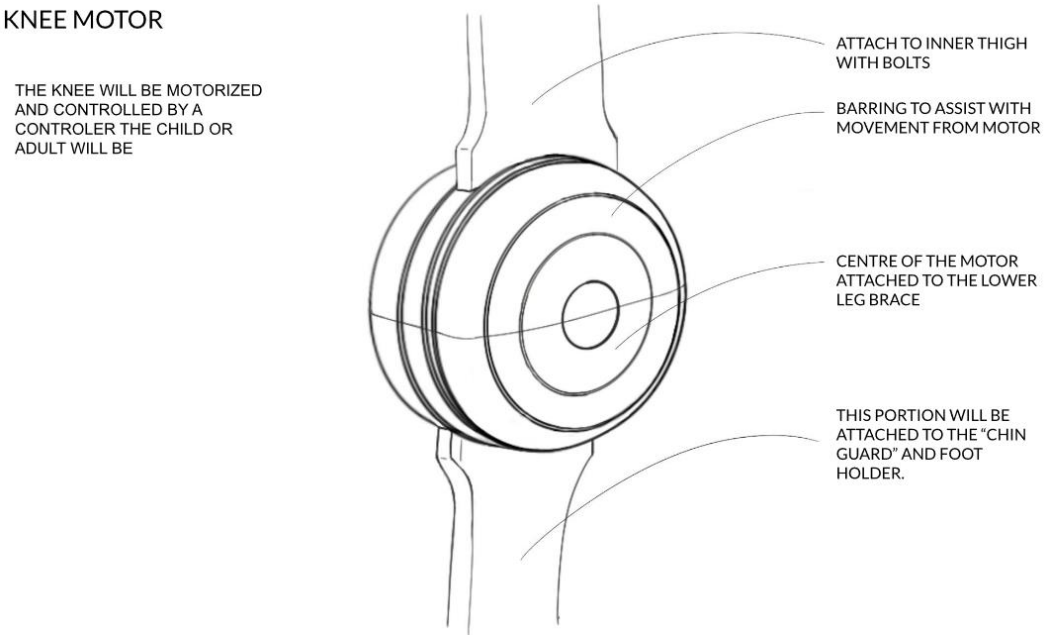


Figure 28 Sketch

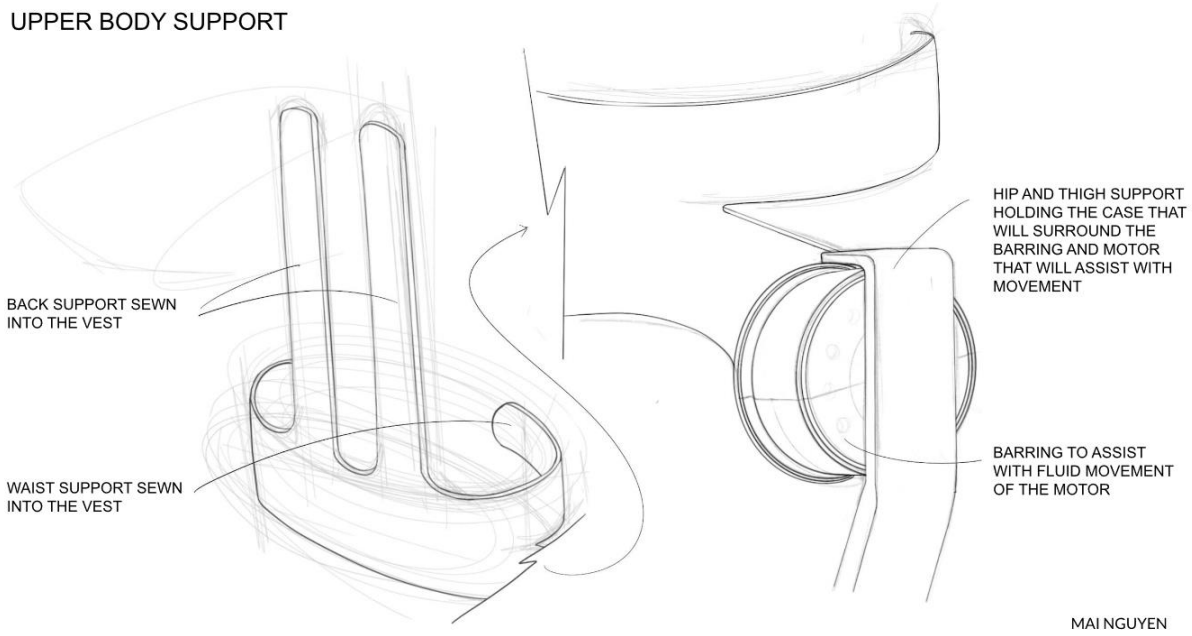


Figure 29 Sketch

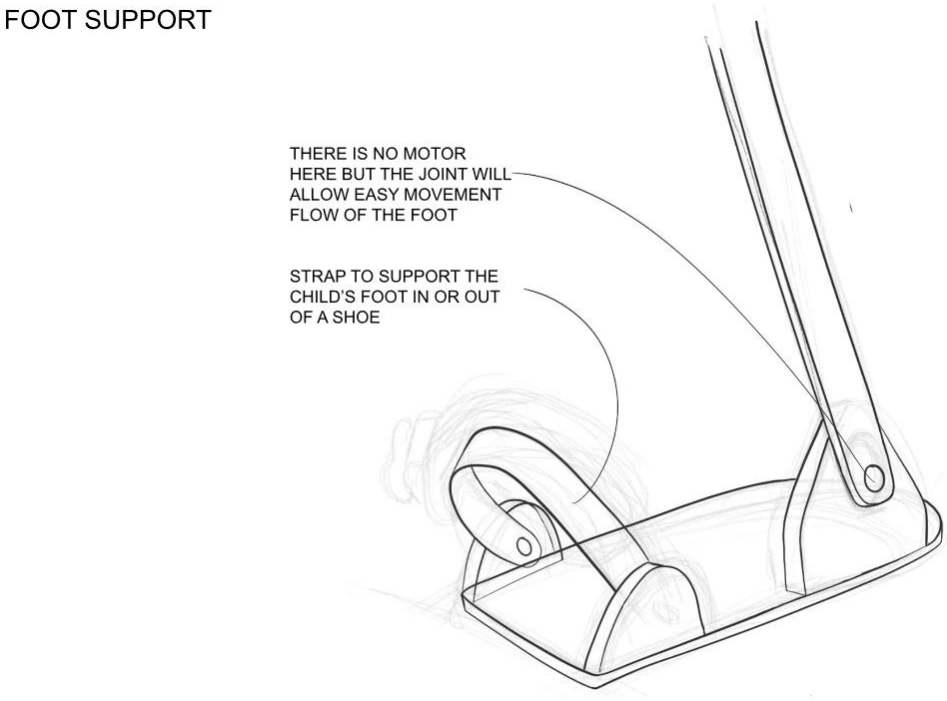


Figure 30 Sketch

4.4.3 Refined Product Schematic & Key Ergonomic

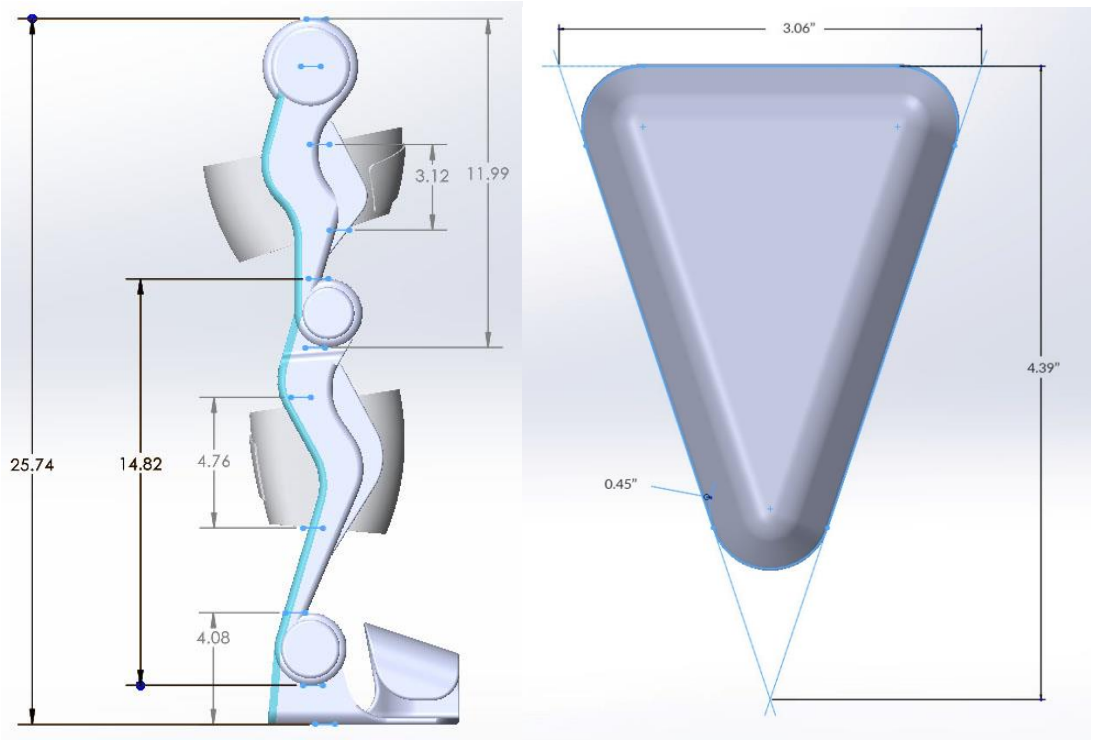


Figure 31 Refined product schematic

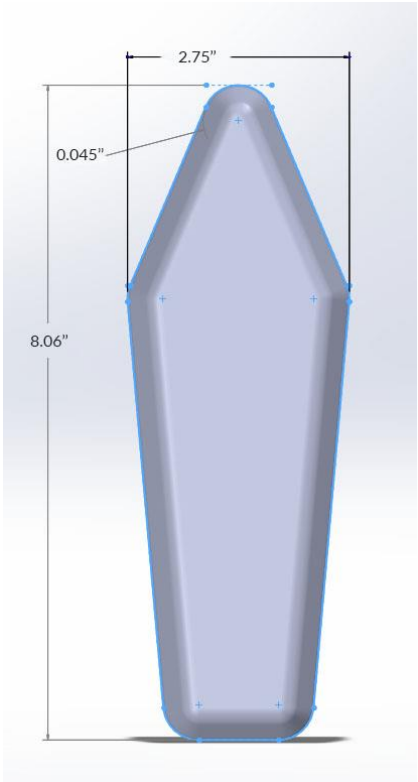


Figure 32 Refined product schematic

4.5 Concept Realization

The design finalization and physical sketch model are covered in this section. Details of the overall product schematic, aesthetic, human factors, and benefits are being finalized.

4.5.1 Design Finalization

Taking into account the previous iterations and the final sketch model revealed detailed changes that were required for a child to utilize the product comfortably and safely. It indicates that the skeletal support of the legs will require more clearance as the child's stance width is limited, which moved the lower legs supports from the inner side of the legs to the outer side of the legs. This change was significant but necessary as it provided the correct amount of clearance needed by the children. The back torso support built into the wearable creates a posture correcting ridged form. The form does not affect the design or aesthetic of Ludere.

4.5.2 Physical Study Models

To gain a better understanding of how the design would fit the body of the child, a full-scale model was created. The mockup was made with foam core and Bristol board. This mockup was used to have a better understanding of the dimensions to fit various sizes of children. The mockup revealed several places where it required a major styling change towards the design.

Figure 33 Sketch Model

Figure 34 Sketch Model

Figure 35 Sketch Model

4.6 Design Resolution

This section will indicate a better understanding of the finalized design. It will cover the designs human interaction, functionality, value, and aesthetic approach. A sketch model of the final design was created at this stage. The knowledge gained will ensure the process of CAD modeling to be seamless in design.

Figure 36 Torso sketch

4.7 CAD Development

This section will go through the process of how the CAD model was developed. Acquiring a free child sized CAD model was difficult and took much searching. The CAD required some adjusting to the correct size of the model to complement the mannequin eventually used for a physical model. The final CAD model was the result of restarting three times over months of modeling.

The structure of the leg supports was created to the finalized design specifications, however required small changes to allow an almost full range of the knee, hip, and ankle bends. The extruded feature was used for the leg and battery parts. The batteries were designed to fit the finalizes specifications. Thigh supports and adjustable straps used surface lofts with guidelines and thickened to achieve the correct curvature.

Figure 37 Battery CAD

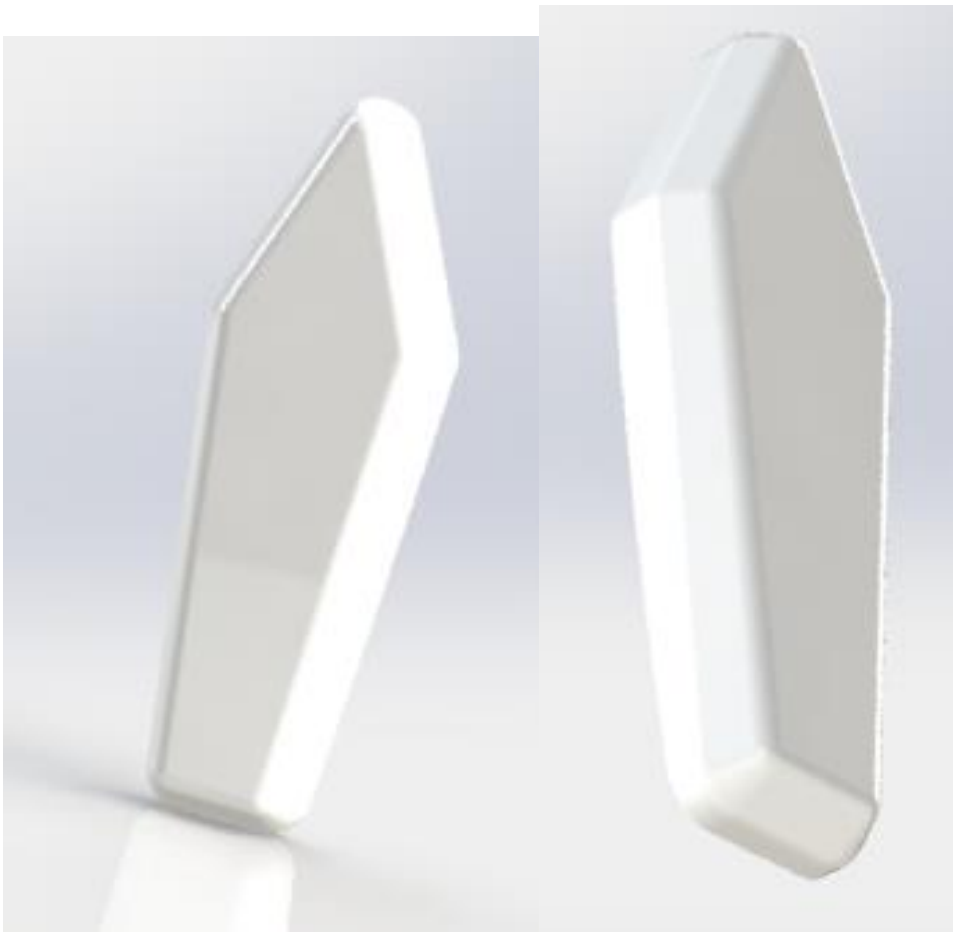


Figure 38 Battery CAD

Figure 39 Battery CAD

Figure 40 Battery CAD

Figure 41 Leg CAD

4.8 Physical Model Fabrication

This section covers the fabrication of the final physical model of Ludere. The skeletal structured leg supports, foot supports, and batteries were 3D printed. The torso was sewn with a polystyrene interior form.

The parts were personally 3D printed and of basic quality. Bondo was used to cover up imperfections. To keep dust out of the house, a homemade sanding box was made. In a homemade sanding box, hours of sanding were spent. More sanding was required after the Rust-oleum 2x Ultra Cover Grey Primer spray had been applied. White and Seaside gloss were utilized as finishing colours. The sketch model was used as a template to cut polystyrene, which was then shaped with a heat gun into the desired shape. The arm control, thigh, and calf supports were made using the same method. Fabric that resembled the textile actuator was cut surrounding the polystyrene

and personally sewn. The figures below depict various stages of the physical model fabrication.

Figure 42 Model process

Figure 43 Model process

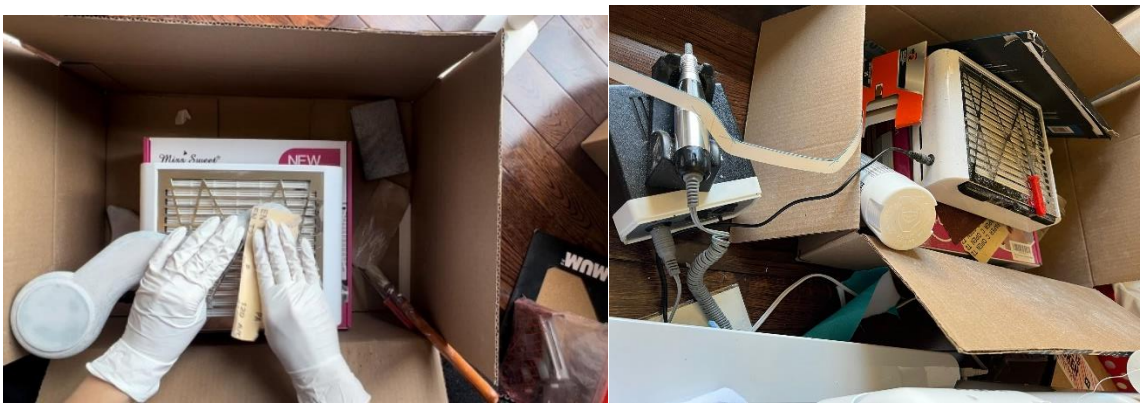


Figure 44 Model process

Figure 45 Model process

Figure 46 Model process

Chapter 5 – Summary

5.1 Summary

5.1.1 Description

Ludere is an exoskeleton for children with Spastic Diplegia type Cerebral Palsy. Ludere will support the child to stand up right and balanced enough to move and play inclusively and independently.

5.1.2 Explanation

Cerebral Palsy effects the abilities such as movement, balance, and posture. Spastic diplegia is a type of Cerebral Palsy that commonly effect the legs. Children with Cerebral Palsy have unvoluntary movement of their body and limbs. A child with disabilities can find it difficult to have social interactions due to their limitations. The social play and interactions with others directly relate to the growth and development of a child mentally and physically. Current mobility aids available are focused solely on the structure of the product and not the aesthetic. This creates an intimidating and bulky structure to which makes it difficult for the child to play or interact with others. Ludere is designed to create a way for children to spend time comfortably and safely with others without assistance.

5.1.3 Benefit Statement

A child with Cerebral Palsy will always require assistance. The parent or caretaker assist the child with everything in their daily lives. The child is frequently attending the many different doctors, specialists, and therapy sessions. These sessions do not allow the child to learn social cues or ways to interact. Limitations with mobility and movement make it difficult to interact and play with other children in a social setting.

Ludere is specifically designed to combat the topic of mobility. Providing the necessary support to targeted muscles, Ludere will help the child stand up right and walk. The carefully designed leg support will structurally hold the legs in position to stand. It has a position for the

child to stand and still feel like they're in a sitting position. The chest muscles will have adjustable straps to be placed in a customized ways for the child to securely keep their torso upright. Adjustable straps on the thigh, calf, and hips will ensure each body part is tightly fastened and comfortable during play time. The social interactions children have a right to will greatly increase their abilities socially and mentally. Building an inclusive life to play Ludere has the potential to be customized for other disabilities and beyond the size limits of children.

5.2 Design Criteria Met

5.2.1 Full Bodied Interaction Design

Ludere was created to help children with Cerebral Palsy have a better quality of life while playing. A child's social development is critical to their development. Making group play enjoyable and simple for everyone to enjoy. It may benefit parents and medical personnel when interacting with children by aiding them in their play. Ludere can bring together a diverse group of children and help them grow socially while having fun. While the children are interacting, the parents/guardians may be able to take a break. Ludere, as a full-body exoskeleton, provides structural support to keep the child mobile, upright, and safe.

5.2.2 Materials, Processes and Technology

Ludere combines different materials to create the exoskeleton. Each material was carefully chosen to maximize the function and minimize the weight of the product. The main structure of Ludere can be recycled to extend the use for the material life and will provide cost savings to create new products for more children. The arm control and legs will layer the dry fibre to the desired thickness, molded into the predesigned shape, and high pressure force will inject the resin required to create the casing. The moulds will be 3D printed with Stereolithography (SLA) and it can be melted down and reused. The foot holder will be molded

into a flexible shape that will form to different shape and size shoes. A rubber sole will be attached to the bottom of the foot holder and on the inside to give the child's shoe a good grip as they walk. The leg casings will house the wiring and motors that will move the legs. The arm control casing will be flexible and house the sensors needed to move the child as desired. A combination of textile actuator and carbon fiber will make up the thigh, calf, and torso support. The carbon fibre for these parts will only partially be used for the inner supports. The textile actuator fabric will be sewn together to house the carbon fibre supports. Using the Theratog technology, the textile actuator straps will be used to customize the placement to support every child that needs it. The straps will have dual lock fasteners sewn in to allow the straps to be moved and refastened directly into the textile actuator on the torso and leg supports.

5.3 Final CAD Rendering

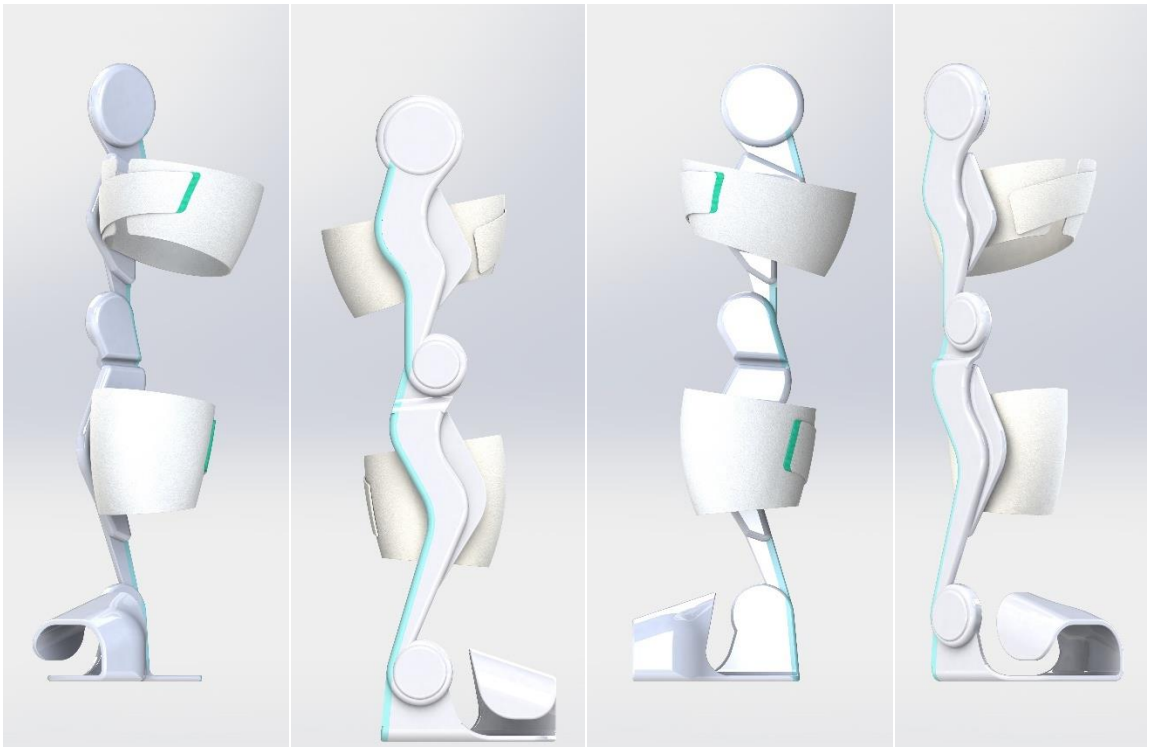


Figure 47 Final CAD

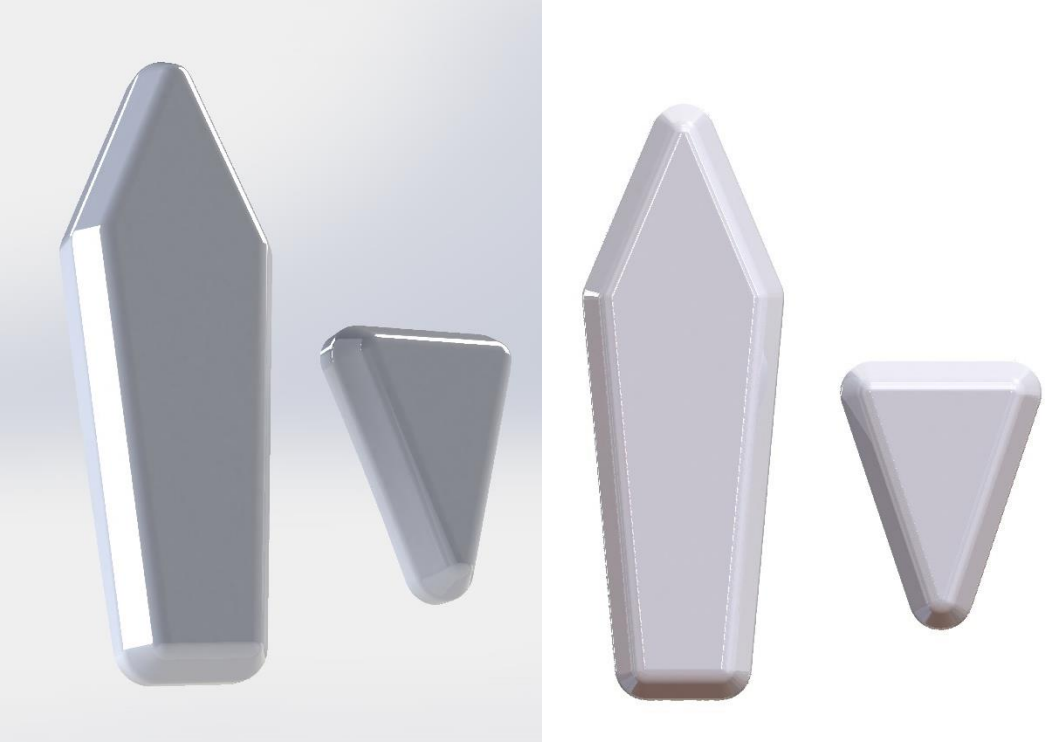


Figure 48 Final CAD

5.4 Physical Model

Figure 49 Final Model

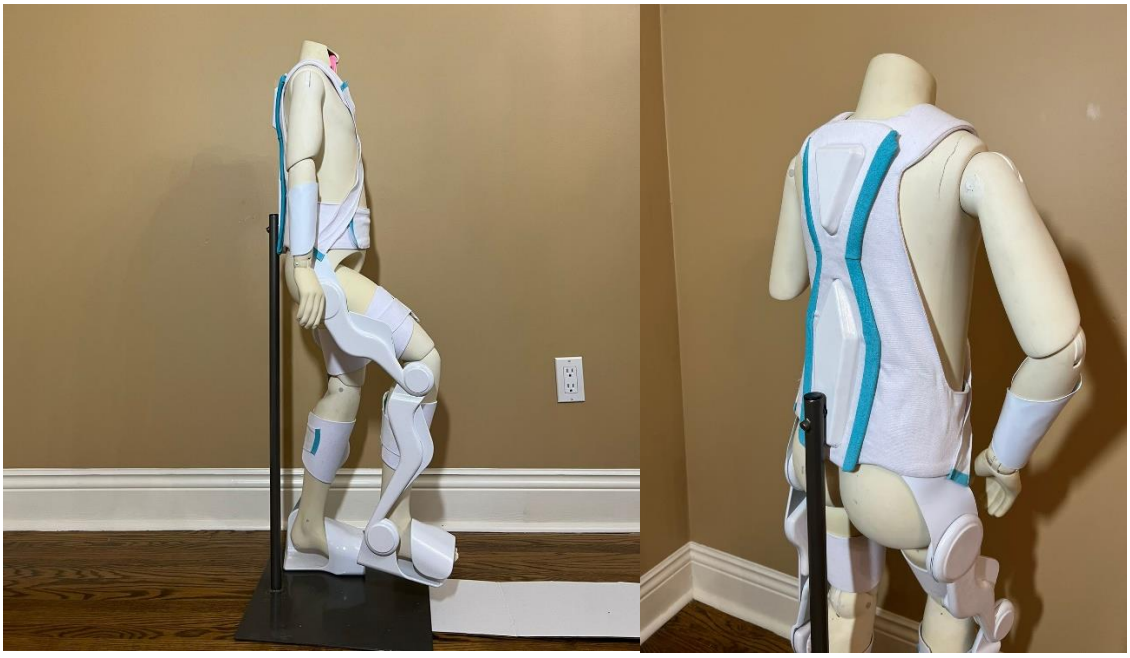


Figure 50 Final Model

Figure 51 Final model

Figure 52 Final model

5.5 Technical Drawings

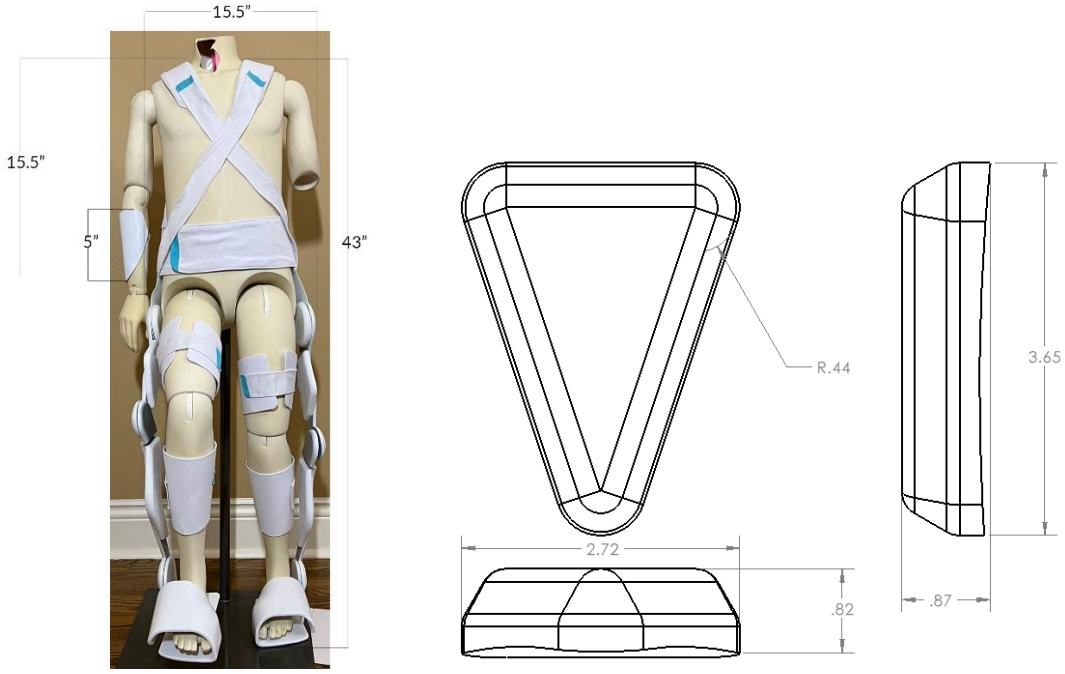


Figure 53 Technical drawings

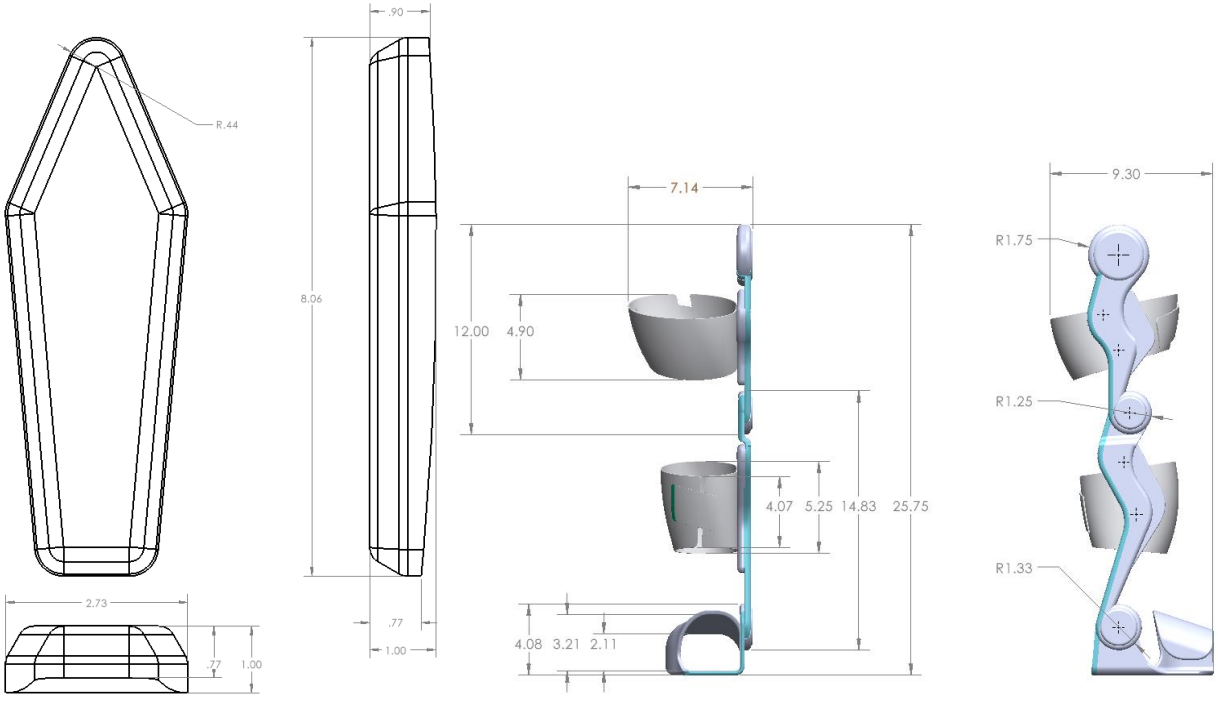


Figure 54 Technical drawings

5.6 Sustainability

After taking all the sustainable information into consideration, the overall design direction will move forward with these materials. As each material is recyclable, the most important factor is the end-of-life stage. The information yields a better understanding of what the end-of-life stage will require. Contacting the correct facilities to recycle the materials to allow Ludere to produce more suits for more children.

Chapter 6 – Conclusion

Ludere is an exoskeleton mobility aid for children with Cerebral Palsy to solely provide a way for the child to play inclusively with others safely and independently. All children crave a sense of independence while children with Cerebral Palsy need to be assisted in almost every aspect of their lives. Ludere contributes to the mental and physical development is beneficial to the child's overall well-being. It empowers the child to be self-sufficient and feel like their own

superhero by directly involving them to be in control of their own movements.

Figure 55 Money shot

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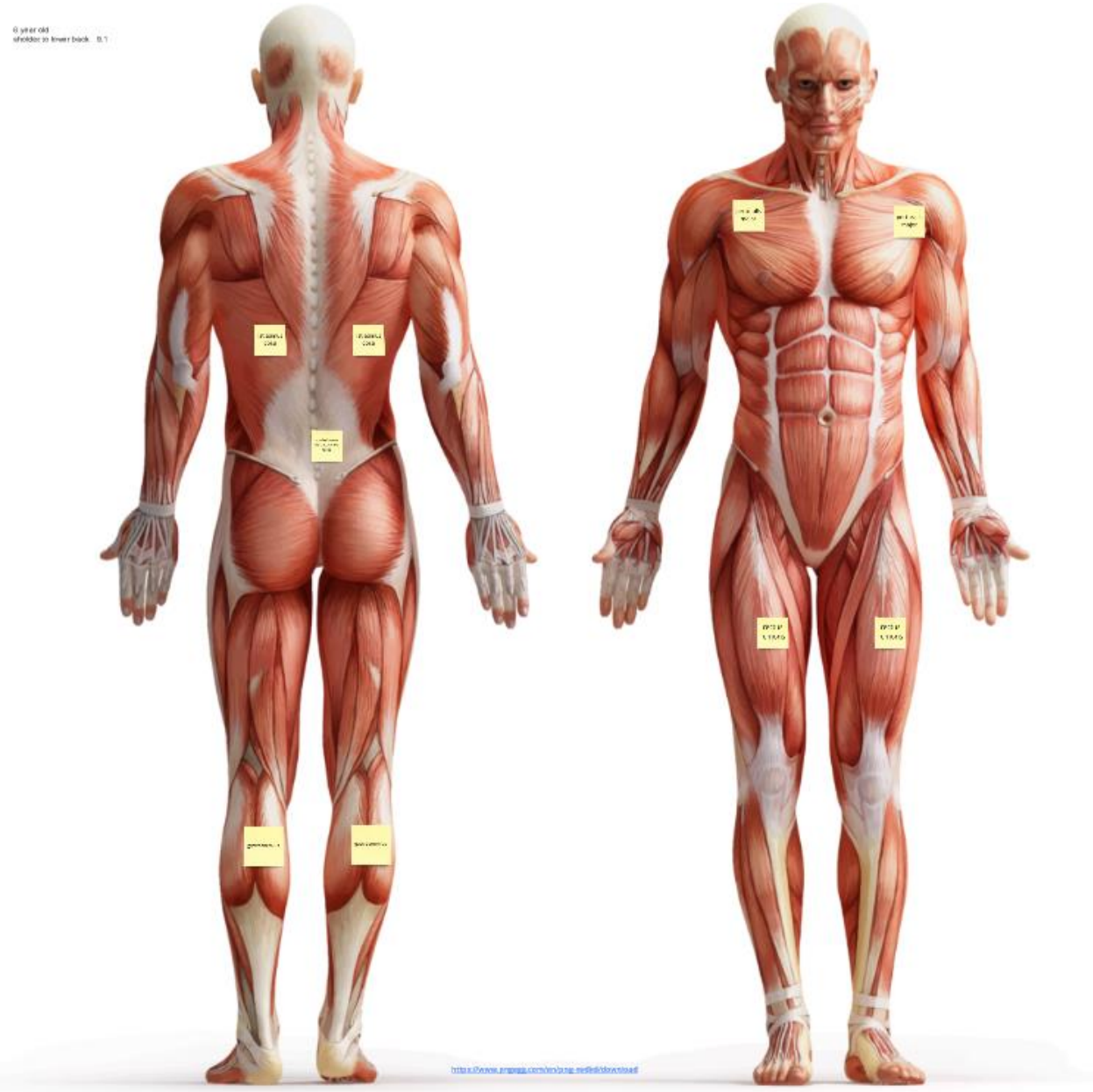
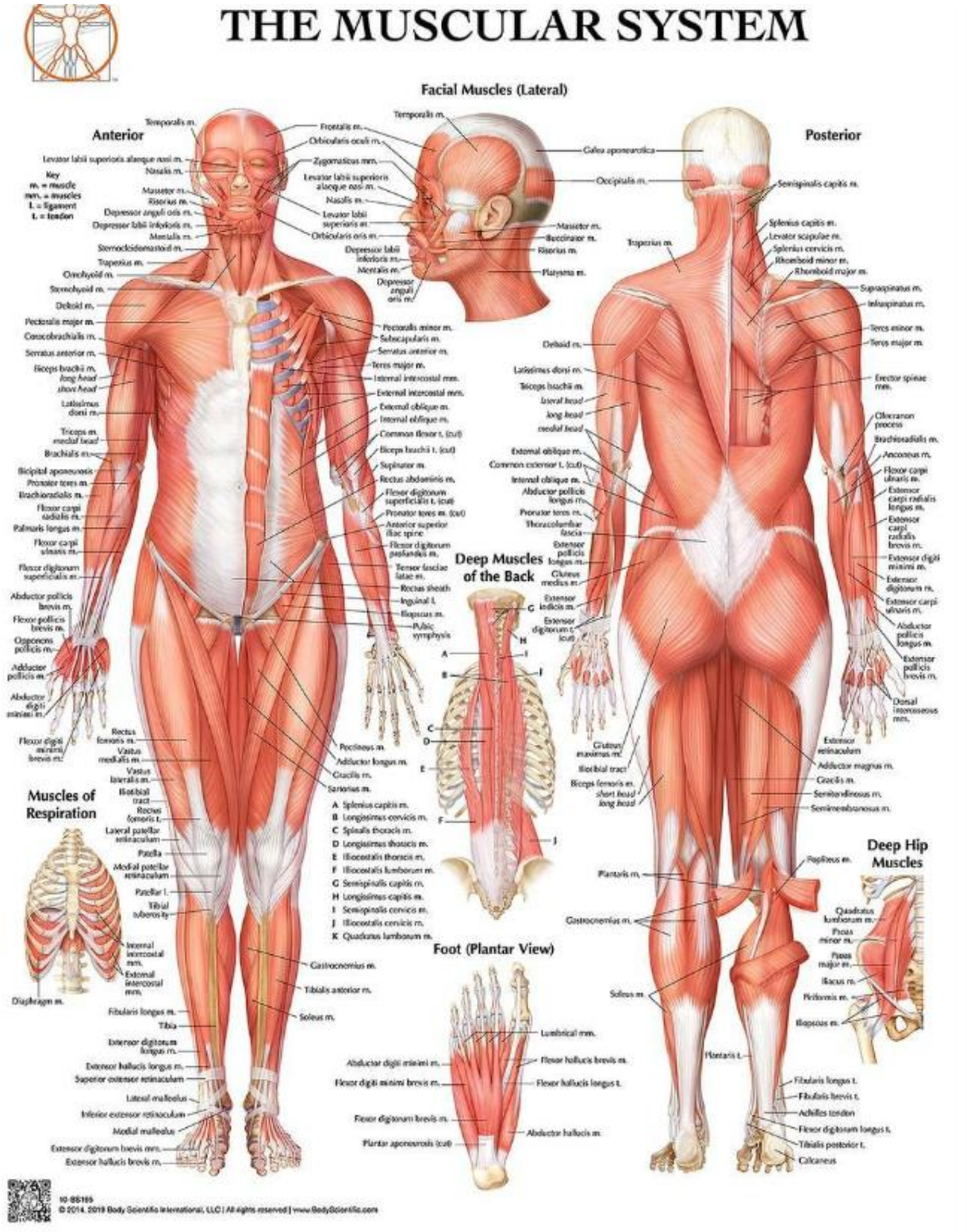
Appendix

A Discovery





https://anatomywarehouse.com/anatomy-of-the-muscular-system-laminated-wall-chart-with-digital-download-code-a-109103

- Seeing how the child reacted almost instantly once wearing the device was amazing.
- The possibilities that this device has for children developmentally in the future is amazing, the *possibilities are endless*.
- This and many devices focus on individual care of children and *not the group aspect* of the development for the children.
- Further exploration to be discovered.

Report 1: Preliminary Literature Review and Information Search

Preliminary Information Search

The objective is to learn how to use the search methods provided, in this report Humber Libraries is the main search tool. To effectively assess information and efficiently process it accurately. Understanding how to scan through articles of information to utilize the important information only.

Problem Statement

Background: Children with Cerebral palsy are often isolated from other children while playing. It is vital for children to have social interactions as they grow up. The interactions will help with developmental growth and confidence.

Needs Statement: Children with Cerebral Palsy need a way to play with other children safely and comfortably.

How is this need being addressed currently? Children have standers that help them stand however the structures are rigid and intimidating. The standers have tables and usually make the child much bigger and taller, which make it harder for children to play.

Article 1

Method

Search Engine: Humber Libraries

Key Words: “play for children with cerebral palsy”

Findings

Citation

Ryalls, B., Harbourne, R., Kelly-Vance, L., Wickstorm, J., Stergiou, N., Kyvelidou, A. (2016). A Perceptual Motor Intervention Improves Play Behaviour in Children with Moderate to Severe Cerebral Palsy. *Frontiers in Phycology,7*, P643. doi: https://doi.org/10.3389/fpsyg.2016.00643 Retrieved from https://www.frontiersin.org/article/10.3389/fpsyg.2016.00643

Key Content:

Abstract

For children with moderate or severe cerebral palsy (CP), a foundational early goal is independent sitting. Sitting offers additional opportunities for object exploration, play and social engagement. The achievement of sitting coincides with important milestones in other developmental areas, such as social engagement with others, understanding of spatial relationships, and the use of both hands to explore objects. These milestones are essential skills necessary for play behavior. However, little is known about how sitting and play behavior might be affected by a physical therapy intervention in children with moderate or severe CP. Therefore, our overall purpose in this study was to determine if sitting skill could be advanced in children with moderate to severe CP using a perceptual motor intervention, and if play skills would change significantly as sitting advanced. Thirty children between the ages of 18 months and 6 years who were able to hold prop sitting for at least 10 s were recruited for this study. Outcome measures were the sitting subsection of the Gross Motor Function Measure (GMFM), and the Play Assessment of Children with Motor Impairment play assessment scale, which is a modified version of the Play in Early Childhood Evaluation System. Significant improvements in GMFM sitting scores ($p < 0.001$) and marginally significant improvement in play assessment scores ($p = 0.067$) were found from pre- to post-intervention. Sitting change explained a significant portion of the variance in play change for children over the age of 3 years, who were more severely affected by CP. The results of this study indicate that advances in sitting skill may be a factor in supporting improvements in functional play, along with age and severity of physical impairment.

Introduction

"The work of children is play." This often repeated saying encapsulates the idea that the active engagement of a child in exploring, investigating, experimenting, and experiencing the world, also known as "playing," contributes to the development of physical, emotional, social, and cognitive development. Engagement in play, particularly complex exploratory and pretend play, is a central activity of early childhood and is linked to the development of cognition, language, problem solving, and social skills (Piaget, 1951; Fewell and Rich, 1987; Singer and Singer, 1990; Hughes, 1991; Farmer-Dougan and Kaszuba, 1999; Russ, 2003; Singer et al., 2006; Bagnato, 2007; Orr and Geva, 2015). Sitting, on the other hand, is an essential motor skill that allows the infant to view and interact with the world in a completely different way and promotes more complex play activities. In the present study, we were interested in the relationship between the development of play and the development of sitting in children with motor impairments. Specifically, we explored whether improvements in a child's ability to sit influences his/her ability to engage in play.

Spontaneous, self-directed play in early childhood, as traditionally characterized (Piaget, 1951; Vygotsky, 1980), requires the use of the hands to reach and interact with objects and toys. The emergence of sitting in typically developing infants at approximately 6 months of age coincides with many skills necessary for play, including improved accuracy in reaching (Rochat, 1992; Harbourne et al., 2013), increased understanding of the spatial properties of objects (Soska et al., 2010), and greater efficiency in visual attention to the environment (Harbourne et al., 2014; Surkar et al., 2015), among others. Sitting stability frees the arms for exploration and object manipulation, and allows the head and trunk to freely move and orient to important information in the environment (Rochat and Goubet, 1995). Sitting posture during reaching appears to rely more on anticipatory processes (Hadders-Algra, 2013). In addition, muscle activation patterns at the onset of sitting are highly variable, and as sitting and reaching develop, these patterns become gradually refined for both tasks (Harbourne et al., 1993, 2013; Hadders-Algra et al., 1996). Studies investigating the development of sitting postural control while reaching suggest that reaching may serve as a perturbation for the maintenance of postural control in infancy (Hadders-Algra, 2013; Harbourne et al., 2013), although hand use clearly increases as sitting develops (Rochat, 1992; Rochat and Goubet, 1995; Harbourne et al., 2013). Thus, evidence from research with typically developing infants indicates that emerging postural control serves to support the development of environmental exploration such that an infant's ability to play and engage in the world improves, which may, in turn, lead to further cognitive advancement.

Although improving postural control may be related to increasing upper extremity skill, a causal relationship is not necessarily evident (Harbourne et al., 2013). Evidence to date reveals contradictory findings regarding the effect of postural control on reaching or play behavior in typically developing infants and infants with developmental delays. Investigations of the specific relationship of proximal (or postural) control to distal (or hand) control do not support the tenet that improving postural control must precede advances in hand skill in the developing child (Loria, 1980; Fetters, 1991). A recent analysis of gross motor function to upper extremity control in children with CP concluded that there was a poor overall correlation between the two, and that the relationship varied between subtypes of CP (Carnahan et al., 2007). In infants with neuromotor impairments, the short-term effect of using a supportive seat to control posture led to no immediate improvement in object manipulation (Washington et al., 2002). On the other hand, providing support at the pelvis in typically developing infants that cannot achieve sitting independently enhanced the coordination between trunk control and reaching (Rochat and Goubet, 1995). Reports from parents have indicated that specific adaptive seating enabled their children to participate more in play activities and address their self-care needs (Rigby et al., 2009) whereas the absence of these devices led to negative outcomes (Ryan et al., 2009). However, a recent systematic review suggested that there are more studies needed to investigate the linkage between sitting postural control and every day life activities (Angsupaisal et al., 2015). Thus, the relationship between sitting postural control and object exploration with the upper extremities cannot be considered as causal, although researchers have identified the co-emergence of the two skills.

Even if postural control influences reaching behavior in typically developing infants, little is known about the specific relationship between the development of sitting and play in children with motor disorders, particularly those with a moderate to severe condition. Poor postural control is associated with limitations in the attainment of functional skills such as mobility and manipulation during the developmental process. However, therapeutic intervention also targets postural control in order to affect upper extremity skill. Research has linked qualitative improvement in reaching with responsiveness to intervention of overall motor skill in children with severe CP (Fetters and Kluzik, 1996) as well as in typically developing infants (Rochat and Goubet, 1995; Out et al., 1998), but the nature of the connection between upper extremity function and postural control is still poorly understood. Adolph and Berger (2006) refer to the 'centrality of posture' as a necessary condition for looking and interacting with the environment around them. However, there are no studies that investigate how the development of sitting postural control would affect play behavior and interaction with objects in children with cerebral palsy (CP) who have not developed sitting independence. Thus, it is important to understand how improvements of sitting postural control ability might influence play behavior in children with CP because play skills reflect the problem-solving skills necessary for independent function.

The prevailing method in physical therapy intervention of children with CP is Neuro-Developmental Treatment (Bobath, 1971). This method emphasizes the reduction of abnormal muscle tone and the facilitation of normal postural reflexes. Assisted movement in specific patterns is encouraged to normalize muscle tone. Facilitation of more normal movement is a primary focus, and it is done through graded stimulation at certain key points of the body (Trahan and Malouin, 2002). Normal postural alignment is emphasized in this approach. A recent review of the body of evidence regarding this intervention approach found little support for its effectiveness in promoting normal motor milestones in any type of condition (Butler and Darrah, 2001; Novak et al., 2013). For this reason we chose a different intervention for the present project.

An alternative approach that is based on perception-action theory is the perceptual motor intervention of Tscharnuter (1993, 2002). This method emphasizes the ecological approach and spontaneous movement based on environmental affordances. Self-initiated, functionally directed movement drives the focus of intervention. This intervention consists of activities that include handling, which gently calls the child's attention to the support surface, and sets up the environment for small increments of movement that the child can utilize to solve a movement problem. Passive movements are not used in this approach. Increased variability of active movement is encouraged, and movements that may be considered abnormal in other approaches are not blocked or discouraged. This perceptual motor approach was used as one of the interventions for a previous project, with preliminary evidence of effectiveness to improve postural control over and above a home program (Stergiou et al., 2006; Harbourne et al., 2010).

Because infants and children with severe motor impairments such as CP are often limited in their ability to manipulate objects (Duff and Charles, 2004; Arnould et al., 2008), measuring and assessing play is a challenging task. Prior to this study, no play-based assessment system had been adapted for use with severely motor impaired children. In the present study, we used a new scale, the Play Assessment of Children with Motor Impairment (PACMI) Scale[1] The PACMI is a modified version of the Play in Early Childhood Evaluation System (PIECES) developed by Kelly-Vance and Ryalls. The PIECES has been empirically documented to be both a valid and reliable measure of play in typically and atypically developing children (Kelly-Vance et al., 1999, 2002; Kelly-Vance and Ryalls, 2005). As described in Section "Materials and Methods," the coding scheme used in the PIECES was expanded in order to capture basic play manipulation behaviors at a fine-grained level. These play behaviors included both successful and unsuccessful child-initiated attempts to manipulate toys.

Conclusion

In summary, in spite of these limitations, the present study documents that emerging play-behavior can be reliably measured in motor-delayed children, that an ecological intervention can

significantly improve sitting ability in children with moderate to severe CP, and that these improvements in sitting may lead to improvements in simple pretend play, particularly for more severely delayed children. This link between motor-development and play is consistent with views with ecological and systems theories that emphasize the significant influence that motor development and self-directed action can have on many areas of development including perception, cognition, emotional development, and others (Campos et al., 2000; Smith, 2005; Maruyama et al., 2014). Importantly, documenting a link between sitting and play in motor-delayed children demonstrates that such links can exist independent of typical chronological development.

Summary Statements

- Developmentally children need to achieve specific milestones as they grow.
- Sitting, being social, perception of distance, and dexterity.
- Sitting is the first steppingstone for development. Even if this is achieved externally, with help of a prop or chair, or naturally.
- Play is different for all children and difficult to assess.

Article 2

Method

Search Engine: Humber Libraries

Key Words: “importance of play with cerebral palsy”

Findings

Citation

Colver, A., Fairhurst,C., & Pharoah, P. (2014). Cerebral. The Lancet, 383(9924), 1240-1249. doi: https://doi.org/10.1016/S0140-6736(13)61835-8.

Retrieved From:

https://www.sciencedirect.com/science/article/pii/S0140673613618358

Key Content:

Abstract

The syndrome of cerebral palsy encompasses a large group of childhood movement and posture disorders. Severity, patterns of motor involvement, and associated impairments such as those of communication, intellectual ability, and epilepsy vary widely. Overall prevalence has remained stable in the past 40 years at 2–3·5 cases per 1000 livebirths, despite changes in antenatal and perinatal care. The few studies available from developing countries suggest prevalence of comparable magnitude. Cerebral palsy is a lifelong disorder; approaches to intervention, whether at an individual or environmental level, should recognise that quality of life and social participation throughout life are what individuals with cerebral palsy seek, not improved physical function for its own sake. In the past few years, the cerebral palsy community has learned that the evidence of benefit for the numerous drugs, surgery, and therapies used over previous decades is weak. Improved understanding of the role of multiple gestation in pathogenesis, of gene environment interaction, and how to influence brain plasticity could yield significant advances in treatment of the disorder. Reduction in the prevalence of post-neonatal cerebral palsy, especially in developing countries, should be possible through improved nutrition, infection control, and accident prevention.

Introduction

In cerebral palsy's milder forms, individuals present with mild spasticity and contracture in one arm and leg on one side of the body, which interferes with fluid movement and fine manual dexterity. The individual might have some sensory inattention to that side of the body and to that visual field, and might have focal epilepsy. At the other end of the spectrum, an individual can present with involvement of the four limbs, with a mixed picture of spasticity and dyskinesia. The individual can have substantial contractures and scoliosis, and therefore require a wheelchair for mobility. They might also have associated severe learning difficulties, cortical visual impairment, and be prone to chest infections.

Cerebral palsy is a syndrome of motor impairment that results from a lesion occurring in the developing brain; the disorder varies in the timing of the lesion, the clinical presentation, and the site and severity of the impairments. The earliest description of the disorder is attributed to the orthopaedic surgeon William Little in 1862.[1] Several attempts to define and classify the syndrome have been made. Recently, the International Executive Committee for the Definition of Cerebral Palsy, proposed the following definition: “Cerebral palsy describes a group of permanent disorders of the development of movement and posture, causing activity limitation, that are attributed to non-progressive disturbances that occurred in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, perception, cognition, communication and behaviour, by epilepsy, and by secondary musculoskeletal problems”. This definition is supplemented by a full explanation of the terms used in the definition.[2]

The complexity of the syndrome is clear from its various classifications; cerebral palsy can be defined according to the anatomical site of the brain lesion (cerebral cortex, pyramidal tract, extrapyramidal system, or cerebellum); clinical symptoms and signs (spasticity, dyskinesia [dystonic and choreo-athetotic forms], or ataxia); topographical involvement of extremities (diplegia, quadriplegia, or hemiplegia); timing of presumed insult (prepartum, intrapartum, or postneonatal); and classification of degree of muscle tone (isotonic, hypotonic, or hypertonic).[3]

Standard classifications are essential for research and transfer of knowledge. The 9th and 10th International Classifications of Disease include many categories of cerebral palsy and substantial inconsistency exists in how clinicians interpret these guidelines.[4] A straightforward classification is needed that can be applied reliably by clinicians and used in registers. Such a classification (with categories of unilateral spastic, bilateral spastic, dyskinetic, and ataxic) and an associated decision tree was developed by the Surveillance of Cerebral Palsy in Europe (European network SCPE) and is now widely adopted.[5]

Conclusions

In the next decade, the brain lesions described by the umbrella term cerebral palsy might be classified by their causal factors coupled with a full description of impairments to body structure and functions they produce. Improved understanding of brain plasticity will probably lead to new treatments or at least better application of existing ones. Management will increasingly focus on promotion of

participation and quality of life, with an expanding range of new technologies directed both to the individual (such as voice synthesisers and robotic assistance) and to the environment (such as intelligent household appliances). Individual and societal attitudes will continue to change to recognise that individuals with cerebral palsy have a right not only to inclusion but also to full participation in society and pursuit of their hopes and aspirations.

Summary Statements

- More studies need to be made to further investigate Cerebral Palsy
- The importance of play is emphasized as it will help further develop the skills children need to grow.
- Different children experience different functional movements of limbs.
- Studying the brain lesions that are in direct correlation with Cerebral Palsy will help finding new ways to create a better quality of for caregivers and receivers alike.

Resources List

Ryalls, B., Harbourne, R., Kelly-Vance, L., Wickstorm, J., Stergiou, N., Kyvelidou, A. (2016). A Perceptual Motor Intervention Improves Play Behaviour in Children with Moderate to Severe Cerebral Palsy. *Frontiers in Phycology,7*, P643. doi: https://doi.org/10.3389/fpsyg.2016.00643 Retrieved from https://www.frontiersin.org/article/10.3389/fpsyg.2016.00643

Colver, A., Fairhurst,C., & Pharoah, P. (2014). Cerebral. The Lancet, 383(9924), 1240-1249. doi: https://doi.org/10.1016/S0140-6736(13)61835-8. Retrieved From: https://www.sciencedirect.com/science/article/pii/S0140673613618358

B Contextual Research (User)

Objectives

Giving children the opportunity of being independent while playing in a group setting to learn

Understanding how a child will react, move, and their process while playing

Observing the child in a party environment held for them at a family home

Method

Who: I will be observing a 7 year old boy with Spastic Cerebral Palsy.

The child has access to different specialists and therapies.

What: I will be quietly observing the party and interactions of the child and how he interacts with the other children at the party.

When: Saturday, October 30th, 2021

Where: It will be an online facetime observation for 2 hours

How: Notes were taken during the entire observation. Questions were asked and answered for the duration.

Results

Arrival

Mother carries child into surprise party.

I was not surprising to see the child get carried into the home. However, it looks increasingly difficult for the mother.

Adjusting

Mother lays child down to undress from outerwear.

Mother helps to make child get comfortable on the couch.

Interact

Friends and family greet child and supports child in a seated position. They ask him questions about the party and if he is enjoying himself.

Mother gets settled in herself and puts away their items.

Rest

Child is visibly drained and needs to rest while the party continues.

The family has laid a thin mattress on the floor for child as he may roll and fall off the couch.

Results

Interact

Child is supported in a seating position while family sings “Happy Birthday”. Mother holds child’s hands to clap along the song. The child is happy and attempting to sing along.

Eat

It is time for the family to eat. The child is put into a highchair while a family member feeds him. First is lunch then his birthday cake. Which he is enjoying very much.

Interact

Watching children younger and older than the child play with each other. The other children would be much rougher with each other and when playing with the child was very gentle.

Discussion

It was interesting to see the children older and younger act in a different manner when playing with each other and when playing with the child with Cerebral Palsy.

The other children wanted to play with the child more often however, felt unable to include him in all types of play.

Adults would treat the child differently and ‘baby’ the child more than the other children.

	sholder to lower back	back of thigh to top of calf	sholder width
6	9.1	11	11
9	10.7	12.75	13
legs			
quadriceps and hamstrings			
gastrocnemius muscles			
abdominals, obliques, lower back and glutes			
erector spinae			

C Field Research (Product)

Product bench marking

1 Wheelchair
- manual/automatic
- Bulky
- Expensive

2 Adaptive tricycle
- Expensive
- Moderate to severe children may not be able to ride without assistance

3 Scooter/standers
- Bulky
- Intimidating
- Sometimes require assistance to get in/out
- Allows child to stand without assistance and be more independent

4 Stair glides/elevator/lifts
- Only available where installed
- Needs assistance to use

5 Adaptive vehicles
- For parents to transport children to and from appointments
- Must be a specialized vehicle

6 Communication devices
- Useful for children to communicate without words
- Confidence building

7 Adaptive art supplies
- Allows all children to participate
- Empowers child with independence

8 Toilet/bath chairs
- Requires assistance
- Bulky

9 Writing tools
- Only for children able to use hands

10 Theratogs
- Allows children to stand with minimal help
- Adds stability to stance

11 Toy cars
- Expensive
- one way to interact

12 Music gloves
- Interactive
- proven results

Video search

Video #1
URL: https://www.youtube.com/watch?v=ZeLL6u4RGhc
Title: How to Do Play Therapy: Role Play With Explanation of Techniques
Length: 8:04 mins

Brief Description:
Therapist showing different types of play and the benefits of Play Therapy.

Relevance to Thesis Topic:
Individual play can be converted to group play for children with Cerebral Palsy

Video #2
URL: https://www.youtube.com/watch?v=rPFhqOTQbAM
Title: TheraTogs Before & After
Length: 0:52

Brief Description:
Physical Therapist shows how this "device" can be used to stabilize children with Cerebral Palsy helping them to potentially walk on their own.

Relevance to Thesis Topic:
Giving children the opportunity to walk on their own can give them more independence to play wit others with confidence.

Video #3
URL: https://www.youtube.com/watch?v=ZzhrTYYwopw
Title: Ball games in sitting. Suitable for all and for those in wheelchairs, disability play and fun.
Length: 2:20

Brief Description:
Games for children to play at home using household objects.

Relevance to Thesis Topic:
Inexpensive things for children to use while potentially interacting.

D Result Analysis

Survey results

How does it feel to have/ know a child with cerebral palsy?

confused | emotional rollercoaster | self blame | one day at a time | appreciate every moment | weary of future

How do you help the child with Cerebral Palsy?

physically moving child | bathing | feeding | going to specialists | play dates | therapy for child/parent

what causes frustrations while caring for your child?

hurts when other kids compare my child to a baby | Big and bulky items for home and outings | Hard to keep child entertained | Isolating for parent and child | Not much play time out of school and with parent | Understanding when child is nonverbal

how do you communicate with your child?

read mind | eye cues | switches | understanding body language | tablets with cues | weary of future

where does your child play with other children?

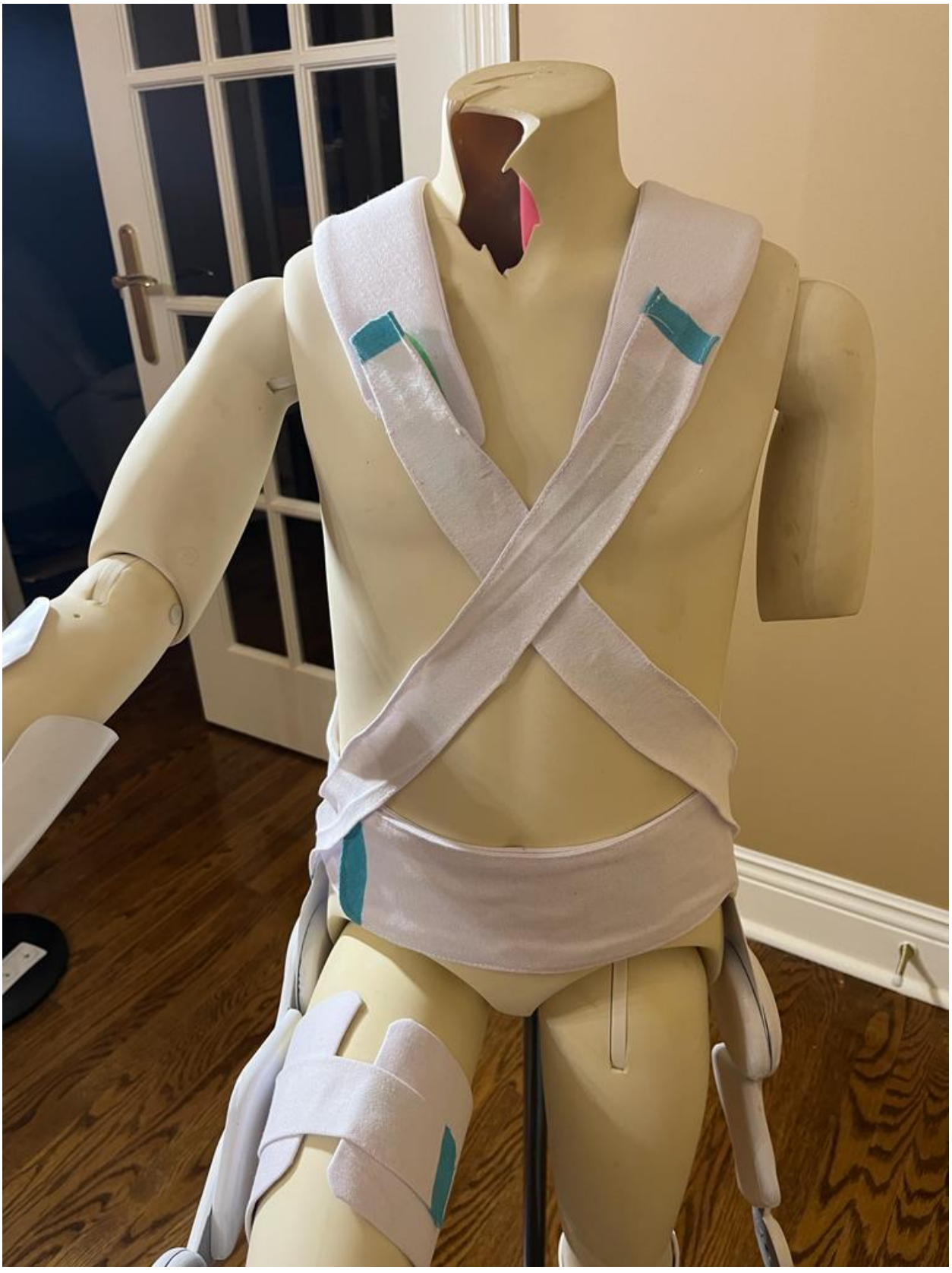
on the floor | with my help | in an assisted device | with their school aides | play dates | at school

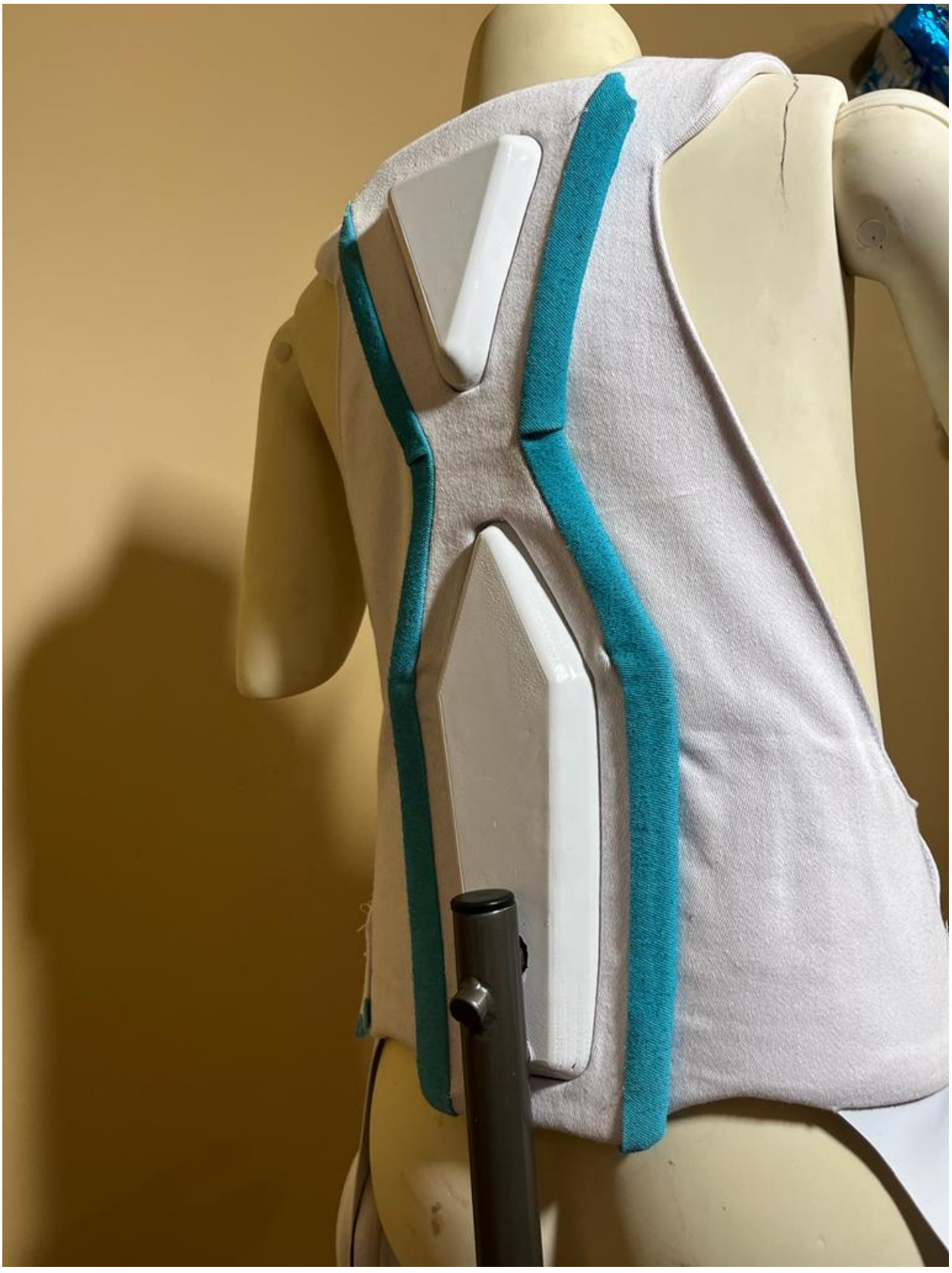
Analysis

	Before	Set up	Task 1	Task 2	Task 2	Task 2	Task 2
User Goals	Arrival	Adjusting	Interact	Rest	Interact	Eat	Interact
User Actions	Child is carried in	Child has help getting undressed from cold weather	Other children and adults come greet child for his birthday	Child lays down	Family and friends sing "Happy Birthday"	Child is put into a high chair and strapped in	Children playing around while child lays to watch
	Child is laid down on couch	Child has many layers to take off	Child laughed, smiled and coo'ed with friends and family	Easily tired the child needs to rest	Mother supports child in lap while holding his hands and clapping along with the song.	Child eats lunch and cake	Occassionally an adult will support child to sit in their lap and help him play with the other children
	child is unable to sit up		Child is supported in a seated position while playing with other children		Child tries to sing the song as well.		
User Thoughts	Excited to go to family's house	I want to play	so happy to be here	I'm tired	I'm having so much fun	mmm I love cake	Child is happy to play with others but long to be independent
Story board/photos							

E CAD Development

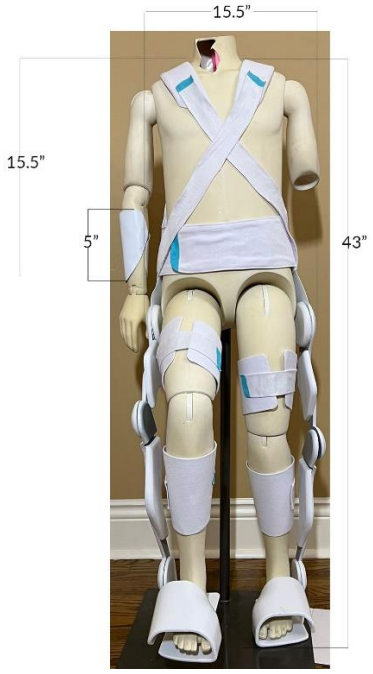
F Physical Model Photographs

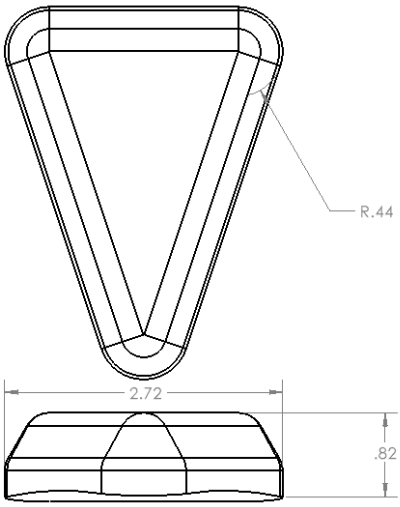


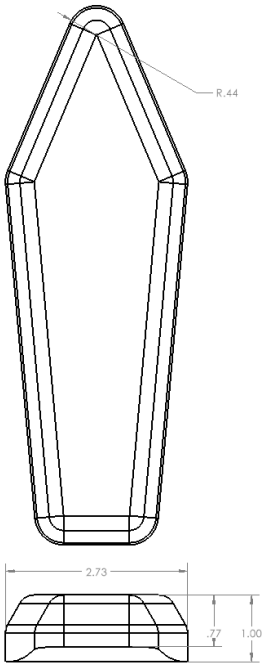


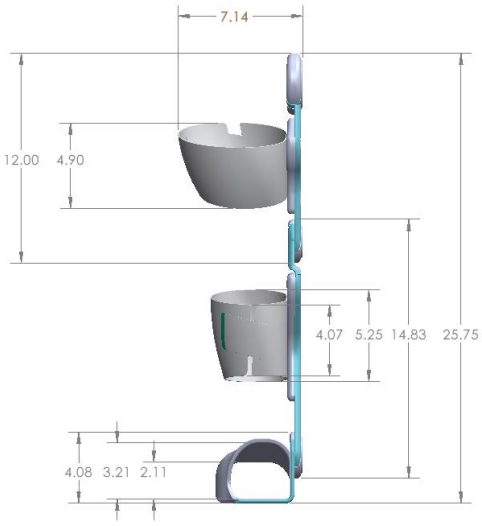

Melissa
Deluxe Wooden
Easy to Perform
Classic Tricks

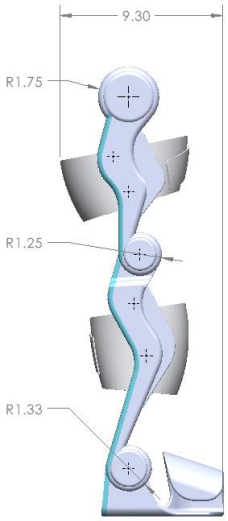
G Technical Drawings











J Approval Forms & Plans

IDSN 4002/4502
SENIOR LEVEL THESIS ONE AND TWO

Humber ITAL / Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / FALL 2021
Catherine Chong / Sandro Zaccolo

THESIS TOPIC APPROVAL:

Student Name:	Mai Nguyen
Topic / Problem Definition:	How may we improve inclusive play for children with Cerebral Palsy?

TOPIC DESCRIPTIVE SUMMARY (Preliminary Abstract)

According to the Centers for Disease Control and Prevention organization, one to four children out of a thousand are born with a certain type of Cerebral Palsy in the world, with eighty percent of Cerebral Palsy cases as spastic. Play and social engagement with the development of children is important and in many cases, difficult for children with Cerebral Palsy. Most adaptive solutions for children with disabilities focus on the fundamentals of everyday life. Children with disabilities need to be socially interactive so they do not feel isolated. Wheelchairs, standers, and adaptive tools are continuing to be developed, however, the focus and application on inclusive play for children with Cerebral Palsy is significantly lacking. The topic of this thesis will focus on socially interactive development of children ages five to nine. How may we improve inclusive play for children with Cerebral Palsy? Giving children the tools to participate as a group for activities will help them socially, physically and confidently in both learning and development through play. Researching the existing practices for the development of children with disabilities and using information gained from interviews will effectively generate a better understanding of ergonomics, and full-bodied human interaction designs.

Student Signature(s):	
Date:	08 October 2021

Instructor Signature(s):	
Date:	08 October 2021

IDSN 4502
SENIOR LEVEL THESIS TWO

Humber ITAL / Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / WINTER 2022
Catherine Chong / Sandro Zaccolo

CRITICAL MILESTONES: APPROVAL FOR CAD DEVELOPMENT & MODEL FABRICATION

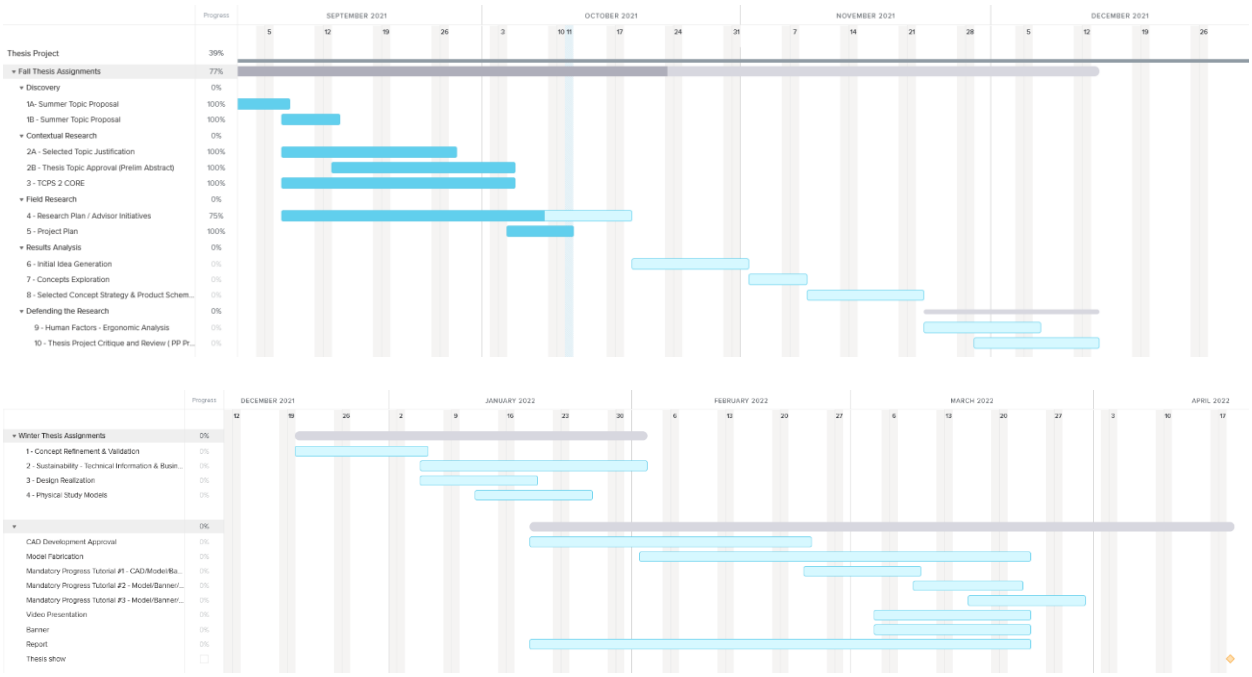
Student Name:	Mai Nguyen
Topic / Thesis Title:	CEREBRAL PALSY INCLUSIVE PLAY & MOBILITY

THESIS PROJECT – DESIGN APPROVAL FORM

Design is reviewed and approved to proceed for the following:	[X] **CAD Design and Development Phase**
Comment:	- Initial CAD started reasonable as of week #7/February 22nd, continue with detailing and refinement. - Refinement CAD progress well as of week #8/March 8th, still need to complete detailing.

Design is reviewed and approved to proceed for the following:	[X] **Model Fabrication Including Rapid Prototyping / 3D Printing and Model Building Phase**
Comment:	- Once CAD is completed, can move forward to model fabrication from week #9 onward.

Instructor Signature(s):	
Date:	8th March, 2022



https://prod.teamgantt.com/gantt/schedule/?ids=2825626#ids=2825626&user=&custom=&company=&hide_completed=false&date_filter=&color_filter=

K Advisor Meetings & Agreement Forms

IDSN 4002 / 4502
SENIOR LEVEL THESIS ONE & THESIS TWO

HUMBER
Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / FALL 2021 & WINTER 2022

INFORMATION LETTER

Research Study Topic:	Cerebral Palsy Inclusive Play & Mobility
Investigator:	Mai Nguyen, (416) 788 – 0826, Ngnm0224@humber.ca
Sponsor:	Humber ITAL, Faculty of Applied Sciences & Technology (IDSN 4002 & IDSN 4502)

Introduction

My name is Mai Nguyen, I am an industrial design student at Humber ITAL, and I am inviting your participation in a research study on various problems that can improve inclusive play children with Cerebral Palsy may deal with. These problems include understanding the importance of a whole body experience fo the children. The results will be contributed to my Senior Level Thesis project.

Purpose of the Study

This study is being conducted as an aid in designing a inclusive method for children to participate in play that is capable of safely and comfortably allowing a child to interact in a game. The product may allow the inclusion to play with ease and fun. With your help, I will have a better understanding of what a child with Cerebral Palsy will face when trying to interact in a group setting. This study is primarily based on understanding ergonomics, human interaction design activities, and user experience aspects of the research area.

Procedures

If you Vollunteer to participate in this study, your input and knowledge will be documented. Our conversations will be documented by means of digital recordings and digital speech to text.

Confidentiality

Every effort will be made to ensure confidentiality of any identifying information that is obtained during the study. In the case of being recorded visually, your face will be masked /blurred or hidden. The information and documentations (photographs) gathered are all subject to being used in the final presentation of the study.

Participation and Withdrawal

Your participation in this study is completely voluntary and you may interrupt or end the study and the session at any time without giving a reason or fear of being penalized.

If at any point during the session, you feel uncomfortable and wish to end your participation, please let the moderator know and they will end your participation immediately.

Humber Research Ethics Board

This research project /course has been approved by the Humber Research Ethics Board. If you have any questions about your rights as a research participant, please contact Dr. Lydia Boyko, REB Chair, 416-675-6622 ext. 79322, **Lydia.Boyko@humber.ca**

INFORMATION LETTER

Conditions of Participation

- ✓ I understand that I am free to withdraw from the study at any time without any consequences.
- ✓ I understand that my participation in this study is confidential. (i.e. the researcher will know but will not disclose my identity)
- ✓ My identity will be masked.
- ✓ I understand that the data from this study may be published.

☒ **I have read the information presented above and I understand this agreement. I voluntarily agree to take part in this study.**

Mimi Luong		2021-11-25
Participant's Name	Participant's Signature	Date

Project Information

Thank you very much for your time and help in making this study possible. If you have any queries or wish to know more about this Senior Level Thesis project, please contact me at the followings:

Phone: (416)788 - 0826

Email: Ngnm0224@humber.ca

My supervisors are:

Prof. Catherine Chong, **catherine.chong@humber.ca**

Prof. Sandro Zaccolo, **sandro.zaccolo@humber.ca**

IDSN 4002 / 4502
SENIOR LEVEL THESIS ONE & THESIS TWO

HUMBER
Faculty of Applied Sciences & Technology
Bachelor of Industrial Design / FALL 2021 & WINTER 2022

PARTICIPANT INFORMED CONSENT FORM

Research Study Topic: Cerebral Palsy Inclusive Play & Mobility
Investigator: Mai Nguyen, (416) 788 – 0826, Ngnm0224@humber.ca
Courses: IDSN 4002 & IDSN 4502 Senior Level Thesis One & Two

I, Mimi Luong, have carefully read the Information Letter for the project of Improving inclusive play for children with Cerebral Palsy, led by Mai Nguyen. A member of the research team has explained the project to me and has answered all of my questions about it. I understand that if I have additional questions about the project, I can contact Mai Nguyen at any time during the project.

I understand that my participation is voluntary and give my consent freely in voice recording, photography and/or videotaping; with the proviso that my identity will be blurred in reports and publications.

Consent for Publication: Add a (X) mark in one of the columns for each activity

ACTIVITY		YES	NO
Publication	I give consent for publication in the Humber Library Digital Repository which is an open access portal available to the public	☒	☐
Review	I give consent for review by the Professor	☒	☐

Privacy
All data gathered is stored anonymously and kept confidential. Only the principle investigator /researcher, Mai Nguyen and Prof. Catherine Chong or Prof. Sandro Zaccolo may access and analyze the data. All published data will be coded, so that visual data is not identifiable. Pseudonyms will be used to quote a participant (subject) and data would be aggregated.

I also understand that I may decline or withdraw from participation at any time, without negative consequences.

I understand that I can verify the ethical approval of this study, or raise any concerns I may have by contacting the Humber Research Ethics Board, Dr. Lydia Boyko, REB Chair, 416-675-6622 ext. 79322, **Lydia.Boyko@humber.ca** or Mai Nguyen, (416) 788 – 0826, Ngnm0224@humber.ca.

Verification of having read the Informed Consent Form:

☒ I have read the Informed Consent Form.

My signature below verifies that I have read this document and give consent to the use of the data from questionnaires and interviews in research report, publications (if any) and presentations with the proviso that my identity will not be disclosed. I have received a copy of the Information Letter, and that I agree to participate in the research project as it has been described in the Information Letter.

Mimi Luong		2021-11-25
Participant's Name	Participant's Signature	Date

PANEL ON RESEARCH ETHICS
Navigating the ethics of human research

TCPS 2: CORE

Certificate of Completion

This document certifies that

Mai Nguyen

has completed the Tri-Council Policy Statement:
Ethical Conduct for Research Involving Humans
Course on Research Ethics (TCPS 2: CORE)

N00811787

Date of Issue: **27 September, 2021**

L Other Supportive Raw Data

M Topic Specific Data, Papers, Publications

Types of Movement Problems

Types of cerebral palsy are diagnosed by the type of brain injury and movement problem. For example, a diagnosis of cerebral palsy may be "spastic diplegia" or "athetoid quadriplegia." The location of movement problems is related to the location of a brain injury and can determine which type of cerebral palsy your child has.

Monoplegia

Monoplegia is a very rare type of movement problem that occurs when only one arm or leg is affected.

Diplegia

Diplegia affects two limbs, which most commonly are the legs. Children with diplegia may have mild movement issues in the upper body as well. Diplegia is commonly a result of premature birth that results in cerebral palsy.

Hemiplegia

Hemiplegia affects one entire side of the body. The arm is generally more affected than the leg and is distinguished by a rigidly flexed wrist or elbow. Prenatal brain bleeding can lead to hemiplegia.

Triplegia

Triplegia occurs when three limbs are affected. This may occur if both legs and one arm cannot move freely.

Quadriplegia

Quadriplegia occurs when all four limbs are affected. The legs are generally impacted more than the arms. Quadriplegia may cause limited control over facial muscles.

Double hemiplegia

Double hemiplegia occurs when all four limbs are affected, but one side is affected more than the other.

Specifications

Dimensions

Product Width:	17.5" to 25.5"
Seat Width:	Rigid: 10" to 18" Folding: 10" to 16" (grows to 18")
Seat Depth:	10" to 18"
Front Seat-to-Floor Height:	13" to 19"
Rear Seat-to-Floor Height:	13" to 19"
Tilt Range:	40° or 55°
Back Height:	Fixed: 19", 22", 25" Adjustable: 16" to 22", 19" to 25" Reclining: 21", 24" MONO Backrest System®: 18.7", 21.7"
Back Angle Adjustment:	Fore (-) 5° to Aft (+) 30°
Center of Gravity (COG) Adjustment:	6"
Shipping Dimensions:	36" L x 37" H x 28" W and 20" L x 20" H x 10" W

Product Information

Model Number:	EIZ5A
Starting Retail Price:	Rigid Frame: $4,260 Folding: $4,490

Performance/Weights

Frame Type:	Tilt (Rigid or Folding)
Frame Material:	Aluminum
Transit:	Yes
User Weight Capacity:	225 lbs. WARNING: Addition of the Z-Finity™ System footrest to this device limits the maximum allowable user weight to 165 lbs. (75 kg).
Product Weight:	**Rigid** Standard Weight: 32 lbs Transport Weight*: 22.8 lbs **Folding** Standard Weight: 35.8 lbs Transport Weight*: 26.6 lbs *excludes footrests, rear wheels, seat pan, armrests, and transit
Average Shipping Weight:	90 lbs. and 15 lbs.

Key user dimensions (inches)				
Select the appropriate Mobile Stander by the **user's overall height**. Choose the model that allows for growth.	 Mini Mobile Stander (K110)	 Small Mobile Stander (K130)	 Medium Mobile Stander (K150)	 Large Mobile Stander (K170)
User's overall height	**25 – 32**	**30 – 40**	**37 – 52**	**48 – 65**

Overview Features Components Sizing Product Resources VIEW PRODUCTS

Item Dimensions (inches)				
Overall length	25	25	32	39
Overall width	25	25½	29	33½
Overall height	22½ – 28	23½ – 30	31 – 39	37½ – 49
Width without big wheels	19½	21	24	28½
Wheel diameter	20	20	27	35
Length of body support	14½	20½	25	32
Width of body support	7 – 10	7 – 10	9 – 12	10 – 14
Height of body support	16½ – 22	22 – 29	29 – 38	36 – 48
Seat pad	N/A	N/A	6 x 7	8 x 11
Item weight (lbs)	28	30	40	65
Maximum working load (lbs)	50	50	120	175

Materials (Basel). 2021 Jul; 14(14): 3778.
Published online 2021 Jul 6. doi: 10.3390/ma14143778
PMCID: PMC8307502
PMID: 34300697

Comparison of Tensile Strength and Fracture Toughness of Co-Bonded and Cold-Bonded Carbon Fiber Laminate-Aluminum Adhesive Joints

Fabrizio Moroni,[1] Alessandro Pirondi,[1,*] Chiara Pernechele,[2] and Luca Vescovi[2]

Ricardo J. C. Carbas, Academic Editor

▸ Author information ▸ Article notes ▸ Copyright and License information Disclaimer

Associated Data

▸ Data Availability Statement

Abstract

Go to: ▸

The purpose of this work is to compare the co-bonding vs. cold-bonding route on the adhesive joint performance of a CFRP (Carbon Fiber Reinforced Polymer) laminate–aluminum connection. In particular, the overlap shear, tensile strength and Mode I and Mode II fracture toughness will be evaluated. The adhesives for co-bonding and cold-bonding are, respectively, a thermosetting modified epoxy, unsupported structural film and a two-component epoxy adhesive, chosen as representative of applications in the high-performance/race car field. The emerging trend is that, in tensile e Mode I fracture tests, the failure path is predominantly in the composite. Mode II fracture tests instead resulted in a cohesive fracture, meaning that, under pure shear loading, the weakest link may not be the composite. The lap-shear tests are placed midway (cohesive failure for co-bonding and composite delamination for cold-bonding, respectively), probably due to the different peel stress values related to the different adhesive Young's modulus. The exploitation of the full capacity of the adhesive joint, hence the possibility of highlighting better, different performances of co-bonding vs. cold-bonding, would require consistent improvement of the out-of-plane strength of the CFRP laminate and/or to someway redistribute the peel stress on the bondline.

Keywords: carbon-fiber, laminate-aluminum joints, co-bonding, cold-bonding, fracture toughness

Clinical Growth Charts

The clinical growth charts reflect modifications in the format of the individual charts, whereby two individual charts appear on a single page, and data entry tables have been added. The clinical charts have the grids scaled to metric units (kg, cm), with English units (lb, in) as the secondary scale. Clinical charts are available for boys and for girls. The available clinical charts include the following:

Infants, birth to 36 months:

1. Length-for-age and Weight-for-age
2. Head circumference-for-age and Weight-for-length

Children and adolescents, 2 to 20 years

3. Stature-for-age and Weight-for-age
4. BMI-for-age

Preschoolers, 2 to 5 years

5. Weight-for-stature