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Development of an

Adaptive climbing hold

for children with cerebral palsy

ZHANG RUI 912612

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Supervisor:
Prof.ssa Maria Rita Canina

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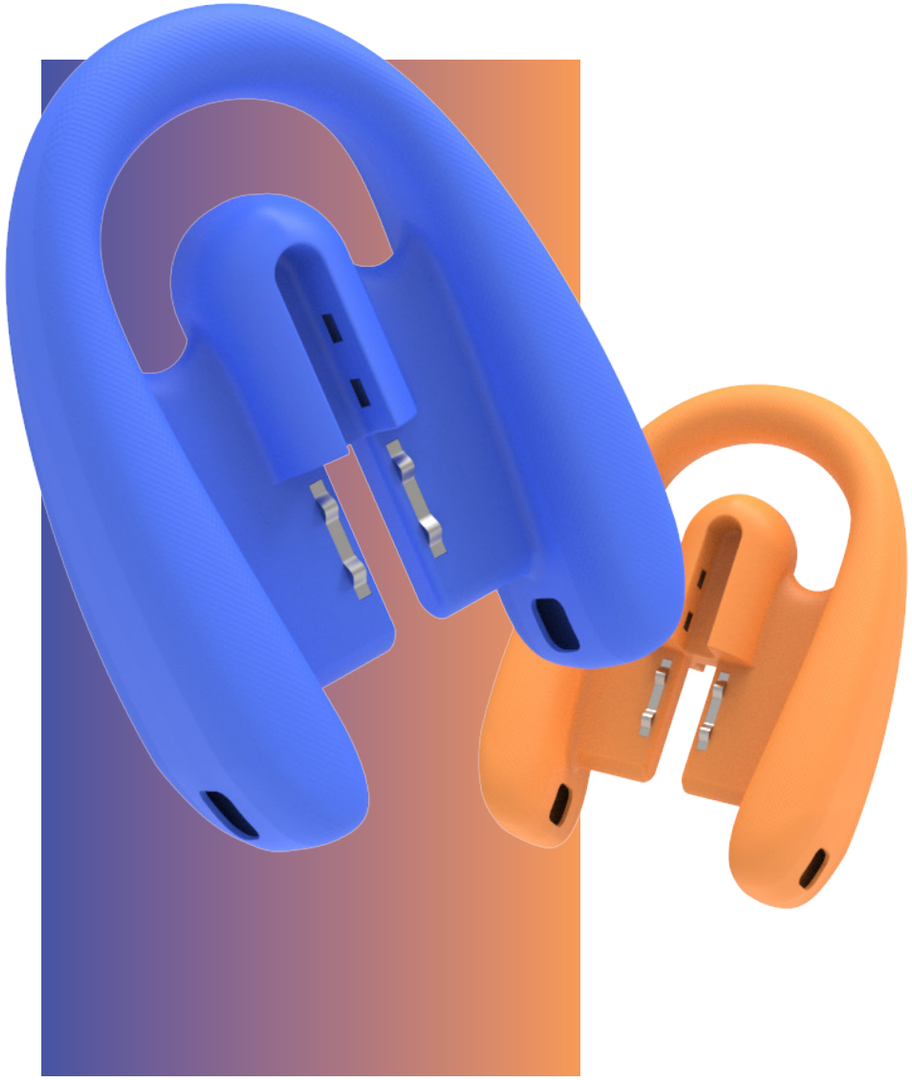

Development of an adaptive climbing hold for children with cerebral palsy

Master Degree in Design & Engineering

Thesis of innovative research

Author: *Zhang Rui 912612*

Supervisor: *Prof.ssa Maria Rita Canina*

Academic Year: *2020/2021*

ACCEPT

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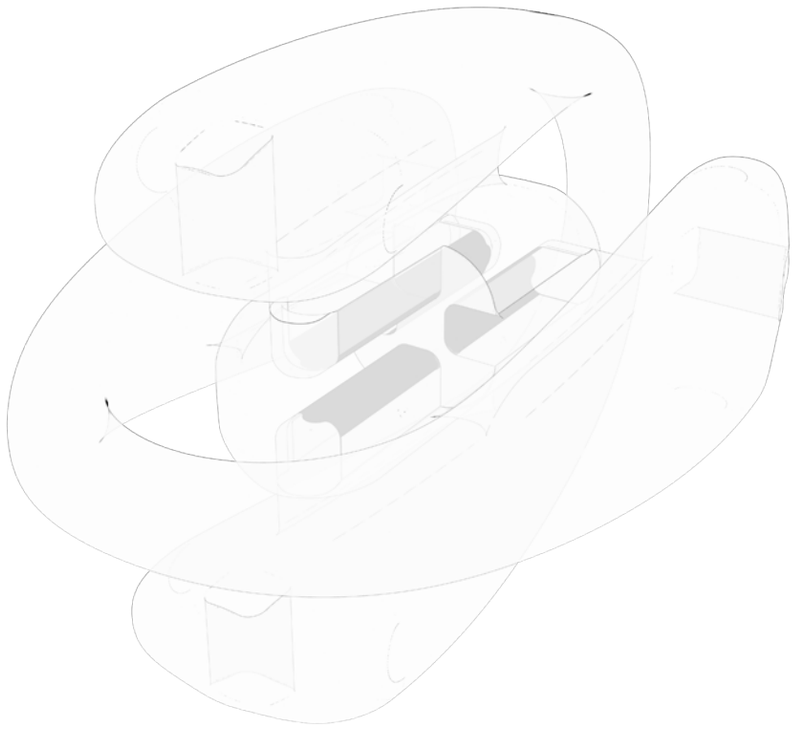

ACCEPT

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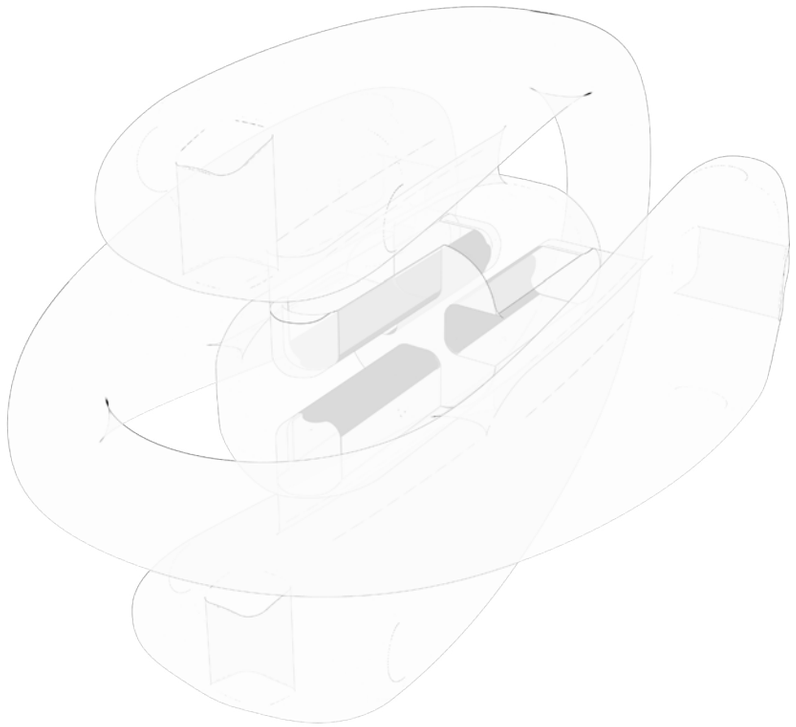
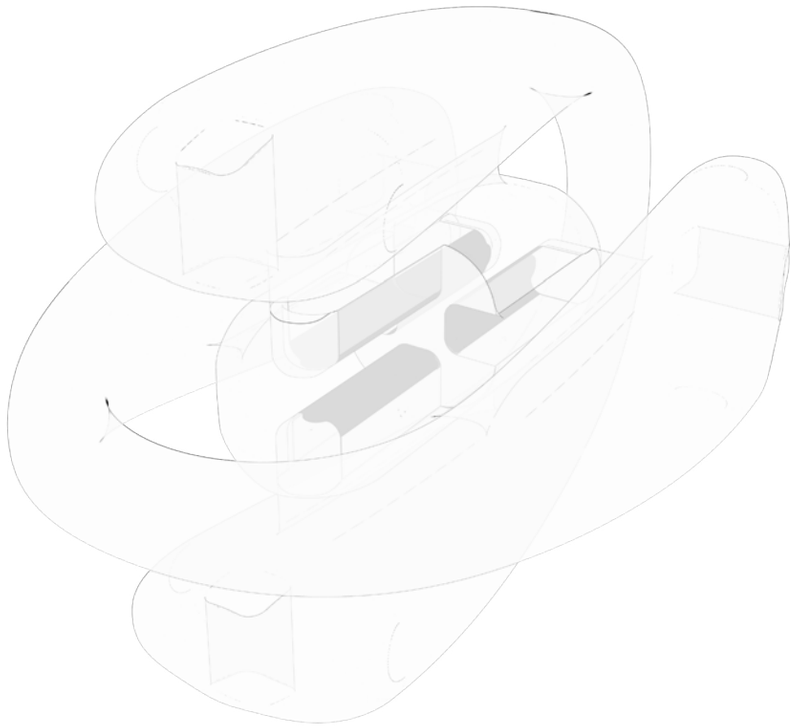
Table of contents

Abstract / en



This thesis addresses the issue of designing a physical therapy product, focusing on climbing training for children with motor disorders
The research aims to adapt the indoor climbing activity to physical therapy for children with cerebral palsy to help them not only improve the motor movement experience but also gain confidence and social communication skills.The thesis is mainly divided into three parts, the first phase is making the desk research, the second one includes different survey method, such as interview, workshop, and observation, about children with cerebral palsy, the last step is project development.
The first part of the thesis introduces the readers to have some basic knowledge about the disease and the sport, indoor climbing, by discussing the history, classification, different therapy methods, etc.
Therefore, the attention is shifted to how and if we can adapt the indoor climbing activities to physical therapy of children with cerebral palsy.
Afterward, different methods of the survey have been used to prove the result of desk research, thanks to the answer of therapists, professional climber, and parents of children, we can easily pay our attention to use a product to make few changes about the indoor climbing in the gym and figure out how to increase the duration of the climbing healing effect.
The development of a hold which can use both at the gym and home is presenting in the last part. The special shape has been designed for the hold, in order to let children have a more grasping method and cater to the need of the toy. In this way, the children are motivated to interact more with the hold, not only previewing or reviewing some feeling of climbing but also have domestic therapy. It is a new area in the market and I really hope the new hold can be used in attracting more and more children with cerebral palsy to have interest in indoor climbing sport and help them live happier.
Thanks to the ACCEPT project which is launched by Polisocial Award 2019 – Politecnico di Milano gives me the opportunity to develop the project and test in the next phase of the project.

Abstract I it



Questa tesi affronta il tema della progettazione di un prodotto di terapia fisica, concentrandosi sull'allenamento in arrampicata per bambini con disturbi motori
La ricerca mira ad adattare l'attività di arrampicata indoor alla terapia fisica per i bambini con paralisi cerebrale per aiutarli non solo a migliorare l'esperienza motoria ma anche ad acquisire sicurezza e capacità di comunicazione sociale.La tesi è principalmente suddivisa in tre parti, la prima fase è quella di la ricerca a tavolino, la seconda include diversi metodi di indagine, come intervista, laboratorio e osservazione, sui bambini con paralisi cerebrale, l'ultimo passo è lo sviluppo del progetto.
La prima parte della tesi introduce i lettori ad avere alcune conoscenze di base sulla malattia e lo sport, l'arrampicata indoor, discutendone la storia, la classificazione, i diversi metodi di terapia, ecc.
Pertanto, l'attenzione è spostata su come e se possiamo adattare l'attività di arrampicata indoor alla terapia fisica dei bambini con paralisi cerebrale.
Successivamente, diversi metodi di indagine sono stati utilizzati per dimostrare il risultato della ricerca a tavolino, grazie alla risposta di terapisti, arrampicatori professionisti e genitori di bambini, possiamo facilmente prestare la nostra attenzione ad utilizzare un prodotto per apportare poche modifiche all'ambiente interno arrampicarsi in palestra e capire come aumentare la durata dell'effetto curativo dell'arrampicata.
Nell'ultima parte si presenta lo sviluppo di una presa utilizzabile sia in palestra che a casa. La forma speciale è stata studiata per la presa, in modo da permettere ai bambini di avere un metodo più di presa e soddisfare le necessità del giocattolo. In questo modo, i bambini sono motivati a interagire maggiormente con la presa, non solo anticipando o rivedendo qualche sensazione di arrampicata ma anche a una terapia domestica. È una nuova area del mercato e spero davvero che la nuova presa possa essere utilizzata per attirare sempre più bambini con paralisi cerebrale per interessarsi allo sport di arrampicata indoor e aiutarli a vivere più felici.
Grazie al progetto ACCEPT che viene lanciato da Polisocial Award 2019 - Politecnico di Milano mi dà la possibilità di sviluppare il progetto e testarlo nella fase successiva del progetto.

1. Introduction

Introduction

1.1 Research area

1.1.1 Cerebral palsy

Cerebral palsy (CP) is a group of permanent movement disorders that appear in early childhood. CP can affect a person's ability to move and maintain balance and posture. while movement problems are the central feature of CP, difficulties with thinking, learning, feeling, communication and behavior often co-occur. While signs and symptoms vary among people and over time. Because of the disorder the children with CP is not only have barrier at the body but also at a heightened risk of developing depression.

Basically, CP is classified by the types of motor impairment of the limbs or organs. There are three main CP classifications by motor impairment: spastic, ataxic, and dyskinetic. Additionally, there is a mixed type that shows a combination of features of the other types. In these three types I will focus on the spastic Cerebral palsy, because it is the most common form of CP, there is 80% children with CP belong to this type. And because of the damaging of motor cortex, the muscles will always be stiff and tight.

Meanwhile, spastic CP usually is described by what parts of the body are affected. In this way, by how much limbs have been affected, spastic CP could also be divided into four forms: spastic monoplegia, spastic hemiplegia, spastic diplegia and spastic quadriplegia. Because of the difficulties of climbing sport, it is more helpful for the mild patients (monoplegia and hemiplegia).

In order to help them improve their daily life, health and well-being, several options have been offered. Such as medications, surgery, occupational therapy, physical therapy, speech therapy and etc. In this treatment, physical therapy is one of the most important forms of treatment for children with cerebral palsy, which can help the children overcome physical limitation, gain confidence and independence, expand range of motion, improve fitness/ flexibility/ balance and posture, increase tactile registration, etc.

Climbing as a common motion of people in their daily life, by adapting indoor climbing sport into physical therapy can really cover the new type of movement in the physical therapy activities.

1.1.2 Indoor climbing

Indoor climbing is an increasingly popular form of climbing performed on artificial structures that attempt to mimic the experience of outdoor rock. It is generally recognized that climbers must optimize strength, power, endurance, flexibility, balance, and neuromuscular control, in order to improve climbing abilities.

The proliferation of indoor climbing gyms has increased the accessibility and thus the popularity of this sport. Since environ-mental conditions can be more controlled in such a setting (indeed anchor points and holds are more firmly fixed), indoor climbing is perhaps a safer and more friendly introduction to the sport.

In general, climbing wall is the instrument of indoor climbing sport basically, construct in the indoor places such as gym. A climbing wall is an artificially constructed wall with grips for hands and feet, therefore, there are several main part about the climbing wall: the basic wall, the climbing holds mattress and accessories.

A climbing hold is a shaped grip that is attached to a climbing wall so climbers can grab or step on it. Climbing holds come in a large array of sizes and shapes to provide different levels of challenge to a climber. By making special climbing holds for the children with CP, the difficulties of the sport will be reduced and children will get more benefit from the sport.

There are several aspects that the hold influence human's behavior. The shapes is highly related to the movement of the hand, the configuration of the holds can influence the posture of the people on the wall.

For the children with cerebral palsy, it is really useful for them to experience the climbing sport they can benefit from the posture, balance and hand movement.

1.2 State of art

There are already few programs around the world, which aim on use indoor climbing sport as a tool for rehabilitation of people with disability of their body. What's more, several climbing product has been developed by combining more activities with indoor climbing.
Despite that, development of the new climbing hold base on the symptom of children with cerebral palsy is a new area of research which can still be widely developed to improve the effective of movement treatment of CP.
Additionally, there are many types of physical therapy treatment which can be combine with the climbing activity to enhance the children's different skills.
While the use of knowledge of CP to develop a hold for indoor climbing sport, in order to help the children with CP to gain more confidence and leave happier in their daily life, is a new area. In the market there are not many adaptive climbing product, not to mention cerebral palsy.

ACCEPT
Adaptive Climbing for CErebral Palsy Training

ACCEPT Project

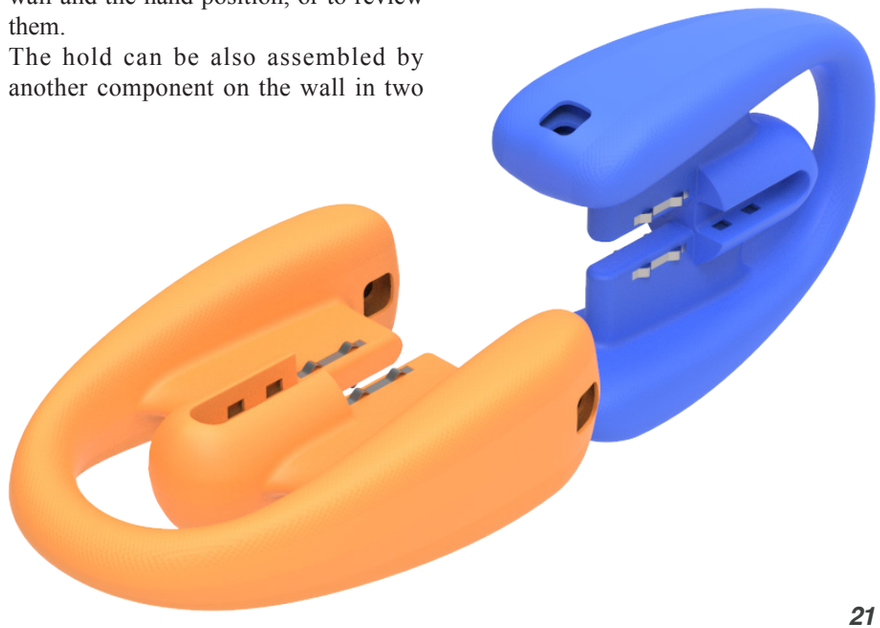
This thesis is to be placed in the wider context of the project ACCEPT (Adaptive Climbing for CErebral Palsy training). Project funded by Polisocial Award 2019 – Politecnico di Milano
In the project, we kindly want to develop an adapted, senzorized and reconfigurable climbing wall, optimized for children with cerebral palsy
starting from this evidence and in partnership with FightTheStroke, the project focusses on sport climbing with the objective of studying, realizing and testing a prototype of an adapted, sensorized, and reconfigurable wall —ACCEPT— designed for the rehabilitation of children between 6 and 13 year old. The research aims at exploring and promoting the role of sport climbing as a therapeutic tool, proposing a solution that is at once training, inclusion, and a means of tracking rehabilitation progresses.
The project team was composed by Alessandro Colombo (DEIB) scientific coordinator, Francesco Ferrise project manager, Marita Canina (DESIGN), Marco Domenico Santambrogio (DEIB), Vittoria Roiati, Francesca Fedeli, PlayMore and FASI (Federazione Arrampicata Sportiva Italiana). The award ceremony was held at the presence of Rector Ferruccio Resta, Andrea Zorzi and Giulia Ghiretti, Paralympic swimmer and PoliMi student, at Off Campus San Siro, the first off-site location recently launched in Milan by our Institution, where Politecnico will combine education, research and co-design activities with local organizations.
In this thesis, I will use all the data that is found during the survey by design group, interview, workshop and camping activities are all included. And my role in the project is develop the climbing hold for the project.

1.3 Reason

In this thesis, the use of climbing wall will be extended to physical therapy which is the context where the project is set.
The aim of this design is to improve the climbing therapy affection and the motivation of children by providing a dedicated hold in the gym for the children with cerebral palsy.
By using the special climbing hold, the children with CP will not only have a well hand movement therapy during the climbing experience, but also have a better domestic training to increase the duration of the climbing healing effect.
Nowadays, the adaptive climbing therapy is more related to the therapist and trainer by using the normal indoor climbing instruments to help the people of CP gain confidence during climbing.
Changing of the inclination of the adaptive climbing therapy is showed in this thesis, climbing sport can be divided into smaller area.

1.4 Result

The design of a climbing hold for better adaption to the children with CP is presented.
The target users are mainly children with spatic hemiplegia cerebral palsy who is around 6 to 12 years old, since theese children can benefit more from the climbing exercise.
This climbing hold allows the children complete all the hand activities yes but not limited to: Open the hand/ Thumb opposition/ Elbow extension/ Hand supination/ etc. In this way, children can begin to know some part of the climbing wall and the hand position, or to review them.
The hold can be also assembled by another component on the wall in two directions. When assemble vertically to the wall the hold can also provide a big plate to let the children have a rest on it.
Thanks to the coneector of the hold that allows the therapist to intergrated more activities on the wall, on purpose of preventing the children get bored about the climbing exercise and encourge them to make more challange and practise.
What is more, when the children use the hold at home, two holds can be assembled as a toy to motivate the children to play with it.



2. Background

2.1 Cerebral Palsy

2.1.1 Introduction

Cerebral palsy (CP) is not only the most frequent pediatric neuromuscular disorder, but also a group of permanent movement disorders that affect a person's ability to move and maintain balance and posture. CP is the most common motor disability which usually presents at birth or in early infancy, and is the most common cause of physical disability in childhood with a prevalence of 2 per 1000 children. Cerebral means having to do with the brain. Palsy means weakness or problems with using the muscles. The common features of the condition are impairment in muscle function, reduced muscle and bone mass, as well as varying degrees of impaired mobility. While movement problems are the central feature of CP, difficulties with thinking, learning, feeling, communication and behavior often co-occur.

The symptoms of CP vary from person to person. A person with severe CP might need to use special equipment to be able to walk, or might not be able to walk at all and might need lifelong care. A person with mild CP, on the other hand, might walk a little awkwardly, but might not need any special help. CP does not get worse over time, though the exact symptoms can change over a person's lifetime.

Doctors classify CP according to the main type of movement disorder involved, which are Stiff muscles (spasticity)/ Uncontrollable movements (dyski-nesia)/ Poor balance and coordination (ataxia). In this way there are four main types of CP: Spastic Cerebral Palsy/ Dyskinetic Cerebral Palsy/ Ataxic Cerebral Palsy/ Mixed Cerebral Palsy

This chapter starts with a brief history of how we found this disease. And Subsequently it will come the detailed description of what CP it is, how we can classify CP. Since the thesis focus on how to adapt the indoor climbing exercise into physical therapy of CP children, so in this chapter target user (which group of children) will be chosen. In the last section, few physical therapies are usually used to help the children with CP will also be introduced.

2.1.2 Brief history

Figure 1. mummy of Siptah with Cerebral palsy

Cerebral palsy has affected humans since antiquity. A decorated grave marker dating from around the 15th to 14th century BCE shows a figure with one small leg and using a crutch, possibly due to cerebral palsy. The oldest likely physical evidence of the condition comes from the mummy of Siptah, which is shown in Figure 1,an Egyptian Pharaoh who ruled from about 1196 to 1190 BCE and died at about 20 years of age. The presence of cerebral palsy has been suspected due to his deformed foot and hands.

The medical literature of the ancient Greeks discusses paralysis and weakness of the arms and legs; the modern word palsy comes from the Ancient Greek words, meaning paralysis or paresis respectively. The works of the school of Hippocrates (460–c. 370 BCE), and the manuscript On the Sacred Disease in particular, describe a group of problems that matches up very well with the modern understanding of cerebral palsy. The Roman Emperor Claudius (10 BCE–54 CE) is suspected of having CP, as historical records describe him as having several physical problems in line with the condition. Medical historians have begun to suspect and find depictions of CP in much later art. Several paintings from the 16th century and later show individuals with problems consistent with it, such as Jusepe de Ribera's 1642 painting The Clubfoot. as shown in Figre 2.

The modern understanding of CP as resulting from problems within the brain began in the early decades of the 1800s with a number of publications on brain abnormalities by Johann Christian Reil, Claude François Lallemand and Philippe Pinel. Later physicians used this research to connect problems in the brain with specific symptoms. The English surgeon William John Little (1810–1894) was the first person to study CP extensively. In his doctoral thesis he stated that CP was a result of a problem around the time of birth. He later identified a difficult delivery, a preterm birth and perinatal asphyxia in particular as risk factors. The spastic diplegia form of CP came to be known as Little's disease. At around this time, a German surgeon was also working on cerebral palsy, and distinguished it from polio. In the 1880s British neurologist William Gowers built on Little's work by linking paralysis in newborns to difficult births. He named the problem "birth palsy" and classified birth palsies into two types: peripheral and cerebral.
Working in Pennsylvania in the 1880s, Canadian-born physician William Osler (1849–1919) reviewed dozens of CP cases to further classify the disorders by the site of the problems on the body and by the underlying cause. Osler made further observations tying problems around the time of delivery with CP, and concluded that problems causing bleeding inside the brain were likely the root cause. Osler also suspected polioencephalitis as an infectious cause. Through the 1890s, scientists commonly confused CP with polio.

Before moving to psychiatry, Austrian neurologist Sigmund Freud (1856–1939) made further refinements to the classification of the disorder. He produced the system still being used today. Freud's system divides the causes of the disorder into problems present at birth, problems that develop during birth, and problems after birth. Freud also made a rough correlation between the location of the problem inside the brain and the location of the affected limbs on the body, and documented the many kinds of movement disorders.

Figure 2. Jusepe de Ribera's 1642 painting The Clubfoot.

In the early 20th century, the attention of the medical community generally turned away from CP until orthopedic surgeon Winthrop Phelps became the first physician to treat the disorder. He viewed CP from a musculoskeletal perspective instead of a neurological one. Phelps developed surgical techniques for operating on the muscles to address issues such as spasticity and muscle rigidity. Hungarian physical rehabilitation practitioner András Pető developed a system to teach children with CP how to walk and perform other basic movements. Pető's system became the foundation for conductive education, widely used for children with CP today. Through the remaining decades, physical therapy for CP has evolved, and has become a core component of the CP management program.
In 1997, Robert Palisano et al. introduced the Gross Motor Function Classification System (GMFCS) as an improvement over the previous rough assessment of limitation as either mild, moderate or severe. The GMFCS grades limitation based on observed proficiency in specific basic mobility skills such as sitting, standing and walking, and takes into account the level of dependency on aids such as wheelchairs or walkers. The GMFCS was further revised and expanded in 2007.

2.1.3 Classification of Cerebral Palsy

CP is classified by the types of motor impairment of the limbs or organs, and by restrictions to the activities an affected person may perform.[80] The Gross Motor Function Classification System-Expanded and Revised and the Manual Ability Classification System are used to .describe mobility and manual dexterity in people with cerebral palsy, and recently the Communication Function Classification System, and the Eating and Drinking Ability Classification System have been proposed to describe those functions.[81] There are three main CP classifications by motor impairment: spastic, ataxic, and dyskinetic. Additionally, there is a mixed type that shows a combination of features of the other types. These classifications reflect the areas of the brain that are damaged.

Motor Cortex Damage

80%

Cerebellum Damage

6%

Spastic

CP is classified by the types of motor impairment of the limbs or organs, and by restrictions to the activities an affected person may perform.[80] The Gross Motor Function Classification System-Expanded and Revised and the Manual Ability Classification System are used to .describe mobility and manual dexterity in people with cerebral palsy, and recently the Communication Function Classification System, and the Eating and Drinking Ability Classification System have been proposed to describe those functions.[81] There are three main CP classifications by motor impairment: spastic, ataxic, and dyskinetic. Additionally, there is a mixed type that shows a combination of features of the other types. These classifications reflect the areas of the brain that are damaged.

Ataxic

Ataxic cerebral palsy is observed in approximately 5-10% of all cases of cerebral palsy, making it the least frequent form of cerebral palsy. Ataxic cerebral palsy is caused by damage to cerebellar structures. Because of the damage to the cerebellum, which is essential for coordinating muscle movements and balance, patients with ataxic cerebral palsy experience problems in coordination, specifically in their arms, legs, and trunk. Ataxic cerebral palsy is known to decrease muscle tone. The most common manifestation of ataxic cerebral palsy is intention (action) tremor, which is especially apparent when carrying out precise movements, such as tying shoe laces or writing with a pencil. This symptom gets progressively worse as the movement persists, making the hand shake. As the hand gets closer to accomplishing the intended task, the trembling intensifies, which makes it even more difficult to complete.

Basal Ganglia Damage

6%

Combination Damage

~

Dyskinetic

Dyskinetic cerebral palsy (sometimes abbreviated DCP) is primarily associated with damage to the basal ganglia and the substantia nigra in the form of lesions that occur during brain development due to bilirubin encephalopathy and hypoxic-ischemic brain injury. DCP is characterized by both hypertonia and hypotonia, due to the affected individual's inability to control muscle tone. Clinical diagnosis of DCP typically occurs within 18 months of birth and is primarily based upon motor function and neuroimaging techniques. Dyskinetic cerebral palsy is a extrapyramidal form of cerebral palsy. Dyskinetic cerebral palsy can be divided into two different groups; choreoathetosis and dystonia. Choreoathetotic CP is characterized by involuntary movements, whereas dystonic CP is characterized by slow, strong contractions, which may occur locally or encompass the whole body.

Mixed

Mixed cerebral palsy has symptoms of dyskinetic, ataxic and spastic CP appearing simultaneously, each to varying degrees, and both with and without symptoms of each. Mixed CP is the most difficult to treat as it is extremely heterogeneous and sometimes unpredictable in its symptoms and development over the lifespan.

Spastic Cerebral palsy is the most common type of CP which affects about 80% of people with CP. People with spastic CP have increased muscle tone. This means their muscles are stiff and, as a result, their movements can be awkward.

Spastic Cerebral palsy is also classified according to the topographic distribution of muscle spasticity. This method classifies children, in Figure 3, as diplegic, (bi-lateral involvement with leg involvement greater than arm involvement), hemiplegic (unilateral involvement), or quadriplegic (bilateral involvement with arm involvement equal to or greater than leg involvement).

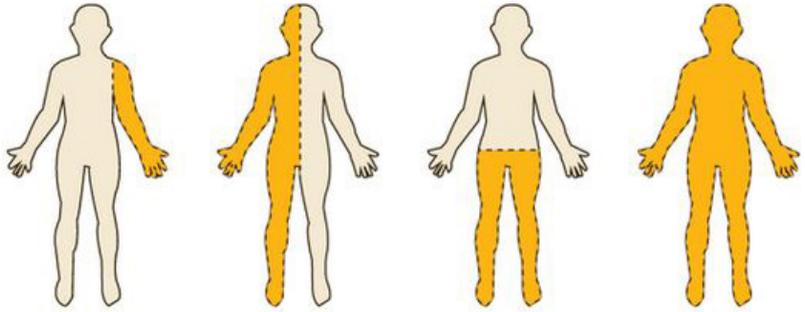


Figure 3. Classification of Spatiic Cerebral Palsy

Monoplegia

Spastic monoplegia- Monoplegia is paralysis of a single limb, usually an arm. Common symptoms associated with monoplegic patients are weakness, numbness, and pain in the affected limb. Monoplegia is a type of paralysis that falls under hemiplegia. While hemiplegia is paralysis of half of the body, monoplegia is localized to a single limb or to a specific region of the body. Monoplegia of the upper limb is sometimes referred to as brachial monoplegia, and that of the lower limb is called crural monoplegia. Monoplegia in the lower extremities is not as common of an occurrence as in the upper extremities. Monoparesis is a similar, but less severe, condition because one limb is very weak, not paralyzed.

Hemiplegia

Spastic hemiplegia—This type of CP affects only one side of a person's body; usually the arm is more affected than the leg.

Diplegia

Spastic hemiplegia—This type of CP affects only one side of a person's body; usually the arm is more affected than the leg.

Quadriplegia

Spastic quadriplegia—Spastic quadriplegia is the most severe form of spastic CP and affects all four limbs, the trunk, and the face. People with spastic quadriparesis usually cannot walk and often have other de-velopmental disabilities such as intellectual disability; seizures; or problems with vision, hearing, or speech.

2.1.4 Therapy

Although, cerebral palsy is a permanent movement disorder that currently has no cure. However, there are a number of treatment options available to help improve the child's daily life, health and well-being.

Treatment will depend upon the type of cerebral palsy that the child has, as well as the severity of the condition. Most pediatricians will create a plan with treatment goals, individualized to meet the child's needs. Although they may differ depending on the severity of the condition, the general goals of a treatment plan typically include ways to:

- Manage medical conditions
- Manage and control pain
- Assist with behavior and social interactions
- Promote independence
- Assistance with eating, bathing, and dressing
- Optimize mobility
- Help with education and learning

Medications

Certain medications help children with cerebral palsy to control symptoms, which can include muscle spasms, uncontrollable limb movements, and seizures. Although medication can be successful, some children will not derive enough benefit from it, and in those instances, surgery may be the next option.

Surgery

Surgery can help people with cerebral palsy reduce muscle spasticity, increase flexibility, and gain function. However, it's important to note that surgery isn't an appropriate option for every child with cerebral palsy, and it also comes with risks.

After surgery, most children will need to be able to participate in post-operative physical therapy and rehabilitation. Sometimes, this isn't an option for some children. The physician will do a complete history and physical examination to determine if the child could potentially benefit from surgery.

It's important to remember that surgery will not magically cure the child's cerebral palsy, but it can help to make the disorder more manageable, which can significantly improve function in daily activities, school, and home life.

Physical therapy

Physical therapy is one of the most important forms of treatment for children with cerebral palsy. Most physicians recommend physical therapy for all children with cerebral palsy, regardless of how minor or severe the disorder is.

Children diagnosed with cerebral palsy will have various degrees of muscle control, balance, and mobility, depending upon how severe the disorder is. Physical therapy helps with these issues by assisting children with balance, posture, crawling, climbing, walking, and muscle strengthening.

Occupational therapy

Occupational therapy assists children with cerebral palsy to improve function while they are at home, at school or in the community, and later in life, at work. This type of therapy helps children successfully carry out tasks needing to be accomplished each day.

Speech therapy

Children with cerebral palsy often have trouble forming words correctly. Speech therapy aims to help children understand language better and communicate more effectively.

Play and social therapy

Regardless of disabilities, almost all children enjoy playtime, and play therapy helps them learn to express themselves better. Although playing is something that tends to be natural and comes easily for most children, those with cerebral palsy may find it a bit more challenging than others.

Behavior therapy

Regardless of disabilities, almost all children enjoy playtime, and play therapy helps them learn to express themselves better. Although playing is something that tends to be natural and comes easily for most children, those with cerebral palsy may find it a bit more challenging than others.

Chiropractic care

Chiropractic care is considered a complementary form of treatment for cerebral palsy that focuses on abnormalities in the musculoskeletal and the nervous systems. Many parents turn to chiropractic care after failing to find success with more traditional treatments. A number of studies indicate that many children with cerebral palsy experienced positive, dramatic results from chiropractic care.

Here are the most common treatments of cerebral palsy, but there are still the other types of therapies didn't be mentioned in the thesis.

2.1.5 Physical Therapy

Benefits

There are a number of benefits of participating in physical therapy, especially for children with cerebral palsy. The primary benefits include helping children overcome physical limitations that significantly interfere with their daily lives.

According to a published studied by the U.S. National Institutes of Health, physical therapy showed "some effectiveness of upper extremity training," but more studies are needed to provide the full outcome of long-term physical therapy.

Another study indicated that although "altering motor prognosis in cerebral palsy remains limited," scientists continue to study more "intense and complex training strategies" that have the "potential for adaptive neural plasticity and recovery."

A physical therapist will construct an in-depth treatment plan, according to each child's strengths and weaknesses. Once the treatment plan is developed, children can benefit from their individualized physical plan which can help with side effects of cerebral palsy that may include:

- Muscle atrophy
- Limited range of motion
- Loss of joint function
- Muscle spasticity
- Pain in muscles and joints
- Joint inflammation
- Rigid muscles

Type of physical therapy

Prior to any child starting physical therapy, an in-depth medical history and physical examination is carried out. In addition to the physical examination, a licensed physical therapist will conduct numerous other tests in order to assess muscle control, functions, and mechanics, such as:

- Range of motion
- Physical strength
- Flexibility and balance
- Endurance
- Joint integrity
- Posture
- Sensory integration
- Cognitive functioning
- Reflexes
- Breathing

Afterward, a care plan is created based upon the child's test results. A physical therapist will then set goals for a child's progress, and work with the child to meet those benchmarks. This typically means the therapist and his or her assistants manipulate a child's body while completing stretches, strength exercises or games with specific movements or purpose.

Often therapy includes instructions for exercises, stretches, posturing and balance to be performed while outside the therapy sessions; at home, school or work.

Where the therapy take place

Physical therapy takes place in several settings, including outpatient medical offices or clinics, inpatient rehabilitation centers, specialized physical therapy centers, skilled nursing centers, hospitals, special education classrooms, and in the home.

The number of physical therapy sessions is dependent on several factors; the most important of these is prescribed treatment of the child. Additional considerations include what adaptive equipment is used in treatment, as well as the abilities of a caregiver to provide additional therapy at home. Insurance coverage can also dictate how often a child attends therapy in a clinical setting. In many cases, a physical therapist will prescribe exercises to be completed at home. The physical therapist or an assistant will train the individual with cerebral palsy, the parent or caregiver and the primary caregivers on how to properly perform exercises at home.

Duration and frequency

For physical therapy, appropriate treatment frequency and duration are important, The frequency included intensive therapy (3 to 11 times per week), weekly or bimonthly therapy (1 to 2 times a week to every other week).

2.2 Indoor climbing

2.2.1 Introduction

Indoor climbing is an increasingly popular form of climbing performed on artificial structures that attempt to mimic the experience of outdoor rock. The proliferation of indoor climbing gyms has increased the accessibility and thus the popularity of this sport. Since environ-mental conditions can be more controlled in such a setting (indeed anchor points and holds are more firmly fixed), indoor climbing is perhaps a safer and more friendly introduction to the sport.

Also the climbing style is different. During indoor climbing, RE in contrast with natural walls where finding a good hold or foothold may be a challenge.

Climbers on artificial walls are somewhat restricted to the holds prepared by the route setter whereas on natural walls they can use every slope or crack in the surface of the wall.

2.2.2 The gym

The proliferation of indoor climbing gyms has increased the accessibility, and thus the popularity, of the sport of climbing.
The climbing gym environment has seen rapid growth also because it serves as a starting spot for most new climbers. In addition, one key aspect of the modern climbing gym is its multidimensionality. Indeed today's gyms might best be considered fitness centers with a climbing focus, where it is often possible to take other courses (like yoga), connect with friends, use the co-working space, or buy gear.
What all gyms have in common is the presence of climbing walls with several designated paths to climb known as "routes", if lead climbing, or "problems", if bouldering. As indoor climbing walls are often used to check the development of climber's ability, these paths are color-coded.

2.2.3 The walls

A climbing wall is an artificially constructed wall with grips for hands and feet, usually used for indoor climbing, but sometimes also located outdoors.
Most modern indoor climbing walls are constructed with plywood or a thick multiplex board, with holes drilled into it over a metal frame (in steel or aluminum), with bolted-on plastic hand and footholds, and sometimes spray-coated with texture to simulate a rock face. The wall can have places to attach belay ropes, and can be used to practice lead climbing or bouldering.
Basically climbing wall can be divided into three parts: the base of the wall, the climbing hold, the mattress.

Plywood
Plywood is a material manufactured from thin layers or "plies" of wood veneer that are glued together with adjacent layers having their wood grain rotated up to 90 degrees to one another. It is an engineered wood from the family of manufactured boards which includes mediumdensity fibreboard (MDF) and particle board (chipboard).

Frame
Wood studs:
A wood stud is a vertical framing component with a small cross section. They are a fundamental element in frame building.

Connection:
Self-drilling screws: Self-drilling screws connect components in one step: they drill, form the thread and fasten. This reduces the installation time.

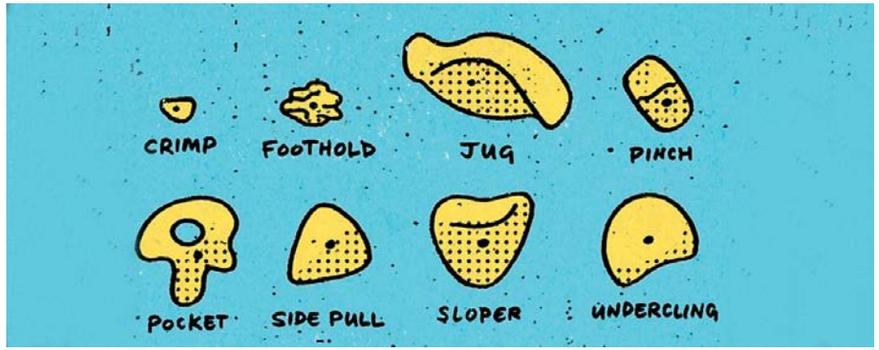
- Nails: In woodworking and construction, a nail is a small object made of metal which is used as a fastener or as a peg to hang something.
- T-nuts: Is a type of nut used to fasten a wood, particle or composite material workpiece, leaving a smooth surface.
- Hex-head bolts: Is a kind of bolt that has hexagonal heads. This threaded fastener has an external male thread on the body and can be uses with a nut or in a threaded hole.

Structural connections: There are several types of structural connectors that can be used to join a frame:

- Joist hanger: these are used in construction to attach a floor or ceiling joist to headers. The joist hanger can support an angled stud or joist.
- Tie plate: these are flat metal plates with holes for screws. They reinforce flat surface joints. T connectors provide a similar function but can only be used when the joint is a T, whereas the tie plate can be used for any angle.
- Framing angle: this is a versatile metal tie used in framing. It can be bent to match the required angle. Bending more than once weakens the joint.
- Angle bracket or corner connector: this is a metal bracket designed to reinforce wood connections at 90 degrees.
- Tie strap: this is a flat metal strap used in a similar way as the tie plate. A tie strap may be chosen over a tie plate due to its more convenient size.

Holds

A climbing hold is a shaped grip that is attached to a climbing wall so climbers can grab or step on it. Climbing holds come in a large array of sizes and shapes to provide different levels of challenge to a climber.



Holds Types

- JUGS: The term “jugs”, derived from the expression “jug-handle”. This is due to their size, indeed jugs are traditionally large holds. Most jugs should have space for both hands to fit on the hold. The term “jug” refers also to a hold’s positivity or degree of concavity. Mini-jugs are holds that are positive but much smaller than traditional jugs.
- PINCHES: Pinches are holds that have two opposing faces which must be pinched to grip, usually by the entire hand, with fingers on one side and the thumb on the other. Technically, any hold in which the use of the thumb in opposition to other fingers is a pinch. Pinches require significant hand strength to use, and are usually used on more challenging routes and boulder problems.
- SLOPERS: Slopers are the least positive of the handholds. They slope down away from the wall with generally a smooth surface, therefore requiring the climber to use an open handed grip and push inwards for maximum friction and in order to gain maximum effectiveness of the hold. These holds are usually considered more difficult and are typically reserved for advanced routes.
- POCKETS: Pockets are holds that have a small opening, only allowing the climber to hold them with one to three fingers. Pockets can be shallow or deep. Single-finger pockets are called monos, and are considered extremely stressful on the tendons. Finger strength must be trained in order to use pockets effectively.
- CRIMPS: Crimps are usually small edges that are just deep enough to fit the tips of fingers into. A technique called “crimping” is used to gain maximum friction on these holds.
- JIBS: A jib is a particularly small foothold, usually only large enough for the big toe, relying heavily on friction to support weight.
- VOLUMES: Volumes are an extremely large type of hold. The volume is attached to the wall and it has pre-placed t-nuts in it to which other holds can be attached. Volumes are especially prevalent in the World Cup circuit, where sometimes entire routes will be constructed from big volumes.

Material

Materials that have been used for climbing holds are wood, rock and polyester resin. Currently, a large quantity of commercial holds are made of polyurethane, since it is lighter, more flexible, and less prone to chipping and breakage than polyester or natural materials.

In an effort to improve the durability of climbing holds, many materials have been experimented with. For example thin, hollow fibreglass holds are extremely light and strong.

PE- Polyester Cristobalite

A precise blend for resin mortar, cristobalite amorphous silica. A texture close to rock offers a unique grip thanks to its hardness. PE resin is cheaper than PU and more UV stable.

Manufacturing process:

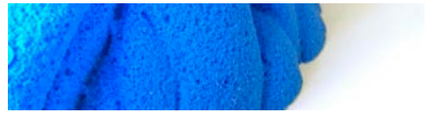
Inject molding/ Die cating

PU-Polyurethane

Features such as superior wear resistance, bright colors, a soft, dry texture and superior strength make it the material of choice for today’s climbing holds.

Manufacturing process:

Inject molding/ Die casting



Fiberglass

Fiberglass is a common type of fiber-reinforced plastic using glass fiber. It is Cheaper and more flexible and stronger than many metals by weight.

Manufacturing process:

Fiberglass hand lay-up operation

Fiberglass spray lay-up operationng

Synrock Ceramic

Synrock is a chemically bonded ceramic, composed mainly of sand grains with an inorganic binding matrix. It is cheaper than Plastic and strong although somewhat brittle

Manufacturing process: Die casting

Wood

The wooden holds can be of almost any size, shape, and dimension, so long as it’s not rotten

Manufacturing process:

Grinding/ Machining/ Drilling

Rock

Manufacturing process:

Grinding/ Countersinking/ Drilling

Mattress

The most common flooring solutions for climbing gyms is the use of mattresses that provide a safe climbing environment.
There are several different solutions on the market suitable for different types of climbing; such as boulder flooring systems, roped floors skirting, training walls padding, drag pads and many others.

2.2.4 The equipment

Proper climbing equipment must be used during indoor climbing. The main items used in the gym are climbing shoes and chalk bags. Also harnesses, ropes and belay devices are require if lead climbing is practiced. Most climbing gyms usually lend all this material.
Some climbing gyms require use of chalk balls (as opposed to loose chalk) to reduce chalk dust in the air and chalk spills when a chalk bag is tipped over or stepped on. Reducing chalk in the air helps to avoid clogging ventilation systems and reduces the dust that accumulates on the surfaces.

Climbing shoes

A climbing shoe is a specialized type of footwear designed for rock climbing. Typical climbing shoes have a close fit, little if any padding, and a smooth, sticky rubber sole with an extended rubber rand.

Chalk bag

A chalk bag is a bag or sack that holds climbing chalk, which the climber dip the hands and fingers into while climbing. This chalk bag is usually hung by a carabiner from the climbing harness or from a simple belt worn around the climber's waist. This allows the climber to re-chalk during the climb with minimal interruption or effort.
Chalk is used by nearly all climbers to absorb problematic moisture, often sweat, on the hands.

Climbing harness

A climbing harness is an item of climbing equipment used for climbing or other activities requiring the use of ropes to provide access or for safety reasons, such as industrial rope access, working at heights, etc. A harness secures a person to a rope or an anchor point.
Most commercial climbing harnesses meet the guidelines and manufacturing standards of organisations such as the Union Internationale des Associations d'Alpinisme (UiAA) or European Committee for Standardisation.

Climbing Rope

These dynamic ropes are typically of kernmantle construction, consisting of a core (kern) of long twisted fibres and an outer sheath (mantle) made of woven coloured fibres. The core provides about 80% of the tensile strength, while the sheath is a durable layer that protects the core and gives the rope desirable handling characteristics.

Belay devices

A belay device is a mechanical piece of climbing equipment used to control a rope during belaying, that improves the safety for the climber. Its main purpose is to allow the rope to be locked off with minimal effort to arrest a climber's fall. Multiple kinds of belay devices exist, some of which may additionally be used as descenders for controlled descent on a rope.

2.2.5 How to climb

Climbing is first and foremost a skill sport, indeed according to Eric Hörst (training expert and author): "No amount of strength or power is going to get you up difficult routes and boulders if you don't know how to move properly and have good climbing technique". The development of technique always precedes the one of force. Indeed, in order to better understand how to climb a specific route, it is important to master the technique, have coordination capacity and prepare a strategy.
Climbing technique is basically a way to link basic foot, hand and body positions into a flowing, upward motion.

There are several studies regarding climbing technique, such as "Il method Caruso", by Paolo Caruso, 90; "Jolly-Power. Metodi di allenamento fisico e mentale per l'arrampicata sportiva" by Alessando Lamberti, or "Training for climbing" by Eric Hörst. Each of them has a different approach to the method and better suits different purpose or type of climbing Despite that, there are some common elements that define the fundamental and basic movements.

Footwork

Given that legs are stronger than arms, it is a fundamental law of efficient climbing that the legs should do the majority of the work. Indeed foot technique is the most useful tool and requires precise and coordinated foot placements. It helps to unload the body weight on the wall, avoiding excessive fatigue.
Good footwork is a skill that one can gain through constant foot focus and practice. There are three basic feet positions:

Edging
Edges are flat or semi-flat ridgelike holds. It is possible to step on them with the front part of the foot, using the inside edge of the shoe.

Smearing
Smearing utilises friction and does not depend on having an edge to weight. It is important to maximise rubber-to-rock contact, using the upper part of the foot and toes to press hard on indentations, dishes, bulges, and other angle changes within the sloping hold.

Hooking
There are two basic types of hooks: heel hooks and toe hooks. To heel-hook it is necessary to place the heel on a hold, usually above or level with the upper body. Toe-hooking is more rare, but useful, especially for keeping the body parallel to the wall on overhanging terrain. Here the foot top goes around a corner, above a lip or in an “undercling” position.

Handholds

The first rule of climbing is to climb on straight arms, in order to not stress out the muscles in the forearm. To climb efficiently it is also important to use the hands for stability, not just to lift the body up.
There are different methods to grab different types of holds.

Jugs
It is important to grab jugs (that are big and easy holds, as illustrated before) using as little energy as possible.

Mono/Pockets
A lot of weight is put on a single finger, so there is a higher chance of injury.

Slopers
Since they are so in-obvious and difficult to use, they require more technique than most holds, such as weight distribution and correct body position. The fingers have to be closer together for adding strength, while the body has to go under the hold as much as possible.

Pinches
this technique utilises opposable thumb. To hold this kind of holds is important to pull down, not out, and activate the core.

Crimps
There are two way of crimping:
- closed hand, where the fingers are curled on an edge and the thumb push over the index finger. This is the most powerful position for tiny holds, but also the most injury-prone as it places high stress on tendons.
- open hand, where the fingers are more relaxed and it is not require the use of the thumb. This position is less likely to injure the fingers, and is the best for building contact strength.

Underclings & Side-pulls
These are two variants of the same idea. Underclings (upsidedown holds) and sidepulls (vertically oriented grips) are holds that are only good when feet and legs are used in opposition with hands.

Balance

Climbing is about balance, movement and efficiency of motion. As David Flanagan writes in his guide to bouldering: “Balance is the glue that binds all the other aspects of climbing technique together”. Indeed climbing requires superior neuromuscular control to maintain balance and stability, especially when climbing faces with limited or tiny foothold.

The term balance can be defined as the relationship between a climber’s centre of gravity and his base of support.

The centre of gravity is the theoretical point where the entire mass of the body is concentrated (it is usually just above the belly button). The base of support is the area created by connecting the points of contact of the body with the wall (so the current hand and foot holds).

There are innumerable climbing methods and techniques. But in most of climbing movements, people climb using these two rules:

The three holds rule

The triangle is a fundamental position of equilibrium on the vertical plane. Indeed this allows to have 3 points of contact on the surface and only the free limb looks for a new ledge on which to anchor in a slow controlled style.

The Left -Right rule In this case a climber climbs a wall using the contralateral hand-foot in pairs, in order to avoid swinginguncontrollably out from the wall.

Center of Gravity

As said before, the CoG is the theoretical point where the entire mass of the body is concentrated. This means that the weight of the entire body acts from this point. Where the climber puts his centre of gravity can decide whether his weight is, on the arms or the legs:

- The body weight is on the legs if the foot used is directly underneath the centre of gravity, or if the feet are one on each side of it. Keeping the body close to the climbing wall helps to distribute the weight on the feet. This position ensures the hands to move from one hold to the next slowly and calmly.
- The body weight is on the arms if both the feet are to one side of the centre of gravity. In this way the arms will get quickly tired.

Balance, stability, and application of force are optimised when the CoG is positioned directly over the feet, forming a line perpendicular to level ground. Although it is not always possible to keep the body in balance, there are different techniques (such as switching feet) that help moving the centre of gravity and reach a more balanced body position.

Body position

Here are illustrated the main used body positions.

Manteling

This technique involves pressing down, using arm and shoulder muscles to drive holds to, or below, waist level. The mantle is generally used to gain a ledge where there are no reachable handholds above.

Slabs

Here the wall angle is less than vertical but the holds can be micro, so it involves a lot of delicate footwork and balance.

Overhangs

On overhanging sections, it is important to conserve energy by moving efficiently. To achieve that it is necessary to hang relaxed, look for good footholds for resting and avoid over-gripping.

Stemming

This technique involves pressing the feet against two opposing planes, bridging the gap to take weight off the arms. Gyms usually have a handful of corners or opposing holds to stem on, while outside stems typically follow dihedrals or corners, and can be gear protected because the corner usually forms a crack.

Layback

The layback is a position of opposition, where feet push against the wall while using consecutive sidepull handholds facing the opposite direction. This technique usually requires a shuffling rhythm. Laybacks are often found on splitter cracks, flakes or in dihedrals with cracks.

Dropknee

This technique helps getting the hips and the body weight close to the wall, so it is useful on overhanging wall. The “twistlock” consists in locking off with one arm, and dropkneeing on the opposite side of the body, increasing the reach on overhangs.

The down side of this movement is that it can irritate the cartilage in the patella and/or blow out the knee tendons and ligaments.

Kneebar

A kneebar allows to bridge the leg, from the toe to the knee, between two areas of rock. Solid kneebars provide “hands-off” rests.

Dyno/Deadpoint

These moves rely on momentum. In a dyno the climber jumps for a hold, sometimes completely detaching from the rock. A deadpoint is more a quick hand movement than a jump.

Backstepping

It is used to elongate the climber reach. It is necessary to stay on a foothold with the outside edge of the shoe, turning the hip so that the outside of it faces into the wall.

Flagging

This technique is often used to prevent that the body swings away from the rock. It consists in sticking one of the legs out as a counterweight against the rest of the body.

2.3 Climb is a new way of rehabilitation

2.3.1 Rehabilitation interventions

Rehabilitation has as its objective the promotion of the child's adaptation to his own living environment and as its ultimate goal the achievement of best possible quality of life of the child and his family.

In recent years there has been a significant evolution in rehabilitation practice. Today the fundamental importance of the child's living environment is recognized for his health and well-being conditions and for the neuronal recognition and recovery linked to the now known neuronal plasticity. The direct involvement of the family, the school, the environments that the child usually goes to during daily life is in fact the key to the success of a treatment.

The rehabilitation intervention of the child with CP can be divided into:

1. Enabling: aimed at promoting skills and competences which, potentially, are present in the child's behavioral heritage, but which, due to neurological damage, may not emerge. This type of intervention is usually used in the early stage of development, even before skills emerge, to promote them and direct them in the most functional direction.
2. Rehabilitation: aimed at recovering functions that have developed difunctionally due to neurological damage, making it difficult for the child to adapt to their environment. The rehabilitation intervention is used when the child has already found and implemented his adaption strategies to the environment, but these are tiring and difficult and can make him suffer from deformity and greater disability.

The rehabilitation project must adapt to each phase of the child's development, this means that the different rehabilitation paths can be very different form each other in the respect of the specific characteristics of each child. It must be discussed and shared with the family and must also provide for an interdisciplinary approach that involves different professional figures. As a product designer what we should do is helping the support teacher to modulate the programs to the child's learning pace.

The most important aspect of rehabilitation is the consistency between the activities carried out in the clinic and the activities carried out at home, it is in fact essential for the child to have the possibility to generalize what he learns in the therapeutic situations, even in the contexts of everyday life.

The key point of rehabilitation is Facing with a task, the nervous system must ask itself questions, it must create perceptual hypotheses to be verified and through appropriate afferents that allow the formulation and verification of perceptual hypotheses (cognitive exercise) forms of movement control are favored and recovery is guided of the adaptive behavioral act.

The year between 1980-1990 saw Prechtl and Touwen as protagonists who revolutionized the perspective of child development. In fact, these consider the motor development of the child, be it normal or pathological, as the result of the interaction between innate sensorimotor patterns and the environment experiences on which these patterns are modulated. The difference lies only in the fact that in the normal child, learning takes place with a wide freedom of choice and is therefore variable, while in the pathological child, due to the fixity and abnormality of patterns, this choice is stereotyped and poor.

In this period, the rehabilitation approaches are:

Conductive education which takes into account the fact that the nature of CP disorder does not only involve motor activity, but also the reception and processing of information, expressive functions and control systems. Conductive education has the objectives 1) to stimulate movements aimed at learning, 2) to favor the skills that are at the basis of a performance (such as

attention, coordination), 3) to analyze tasks, both simple and complexes, 4) reinforce the control of behavior through language.

Motor learning in guide play, which comes from the intuitions of Colli-Grisoni. This approach anticipated by years the conceptions relating to the child's proactive nature and the role of the subject of action. The therapeutic goal is given by learning the qualitatively better performances, in significant contexts.

The rehabilitation approach according to Perfetti (which we will explore further on), considers rehabilitation as a learning process in pathological conditions.

" The recovery of function after injury to the central nervous system must coincide with the acquisition of evolved behavioral patterns, which imply the ability to elaborate significant sequences, that is, such as to allow the verification of perceptual hypotheses" (Perfetti, 1981).

New approaches

Advances in neuroscience have called into question neuromuscular facilitation techniques used in the past that were based on stimulating reflexes or activating motor patterns from the outside that the child was then unable to use independently to meet their needs.

The therapeutic approached currently accredited by the Rehabilitation Services are based on scientific evidence and refer to Motor Learning theories which are based on certain assumptions such as the centrality of the child, who has the fundamental need to feel active and involved. The environment, the proposal of functional activities tailored to the in-dividual child, the personalization of the context and the safeguarding of the child's emotional-relational and affective dimension.

Fedrizzi, in collaboration with GIPCI, described as follows the new therapeutic approaches inspired by the most recent discoveries in neu-roscience such as Motor Learning, Constraint-Induced Movement Therapy, intensive Bimanual Training, Action Observation Therapy, Virtual Reality and Robotics.

In the Motor Learning approach, the most important requirement for the child to acquire greater control of motor sequences and learn more advanced skills in every area of his life is proactive. The child must therefore be solicited and eventually guided to formulate projects on action to solve the problems posed by the environment and by the therapist, who must initially create a playful context that evokes activities of daily life and evaluate the ways in which the child develops an action plan, a motor program or an executive outline. It will be the therapist's task to bring out through changes in the context, the "best performance" of that child,

In Motor Learning, the therapist thus becomes a "motor teacher", an attentive and flexible guide who, knowing the characteristic of the in-dividual child, favors his initiative, helps him in choosing an action plan, guide him in controlling the different phase carrying out an activity.

Therapy with induced constriction of the healthy limb is one of the most discussed rehabilitative intervention methods today and is aimed at the child with hemiplegia. The CIMT focuses on increasing the use of the affected limb in one-handed activities in order to avoid learning to non-use. The main purpose is to modify the learned behavior from non-use so that the hemiplegic limb is "counter-conditioned" to act.

This intervention is effective in improving the skill of reaching and grasping the paretic hand.

In the practice of occupational therapy, bimanual training for the hemiplegic child has been routinely used since the 1970s to encourage the learning of praxis patterns in the activities of daily life. However, only recent years, in relation to the spread of Constraint Therapy, some controlled experimental studies have been published that report the results of bimanual training in children. The first intensive bimanual trail for the child with hemiplegia was published by Gordon et al.(Gordon et al, 2007). Children treated for a short time (10 days) showed significant

improvement through several scales that analyzed bimanual activities.
Observation and motor imitation represent a type of rehabilitation approach that can also act on the reorganization of neuronal circuits the system of " mirror neurons". Motor imitation can facilitate a recovery of impaired neuronal and motor circuits, promoting brain plasticity through the use of multiple sensory afferents. The new therapeutic approach of Action Observation Therapy (AOT), still in an experimental phase, is based on the concept that the simple observation of another person who performs a certain action is able to facilitate the learning of its execution (learning by imitation) (Parente et al, 2011). AOT appears to be a promising rehabilitation tool for children with CP, well rooted in neurophysiology and easy to apply;
Speaking of rehabilitation therapy, it is good to distinguish the concept of therapeutic maneuver, understood as a repetitive activity not participated or passively performed, aimed at automating movement, therapeutic task that favors the result of the action rather than the motor patterns used to achieve it. It is good to always make the work to be done rewarding.
The game that promotes a privileged psycho-affective and relational setting would favor the acquisition of motor skills also exploiting the creative channel.
The playful learning context stimulates creativity and intentionality, but it is a therapeutic approach, of a new meaning, in which the solution of the problem built in a playful environment aims at the exercise of predetermined and repetitive patterns.

2.3.2 Cognitive therapeutic exercise

Cognitive Therapeutic Exercise (ETC) is a rehabilitative method that considers rehabilitative method that considers rehabilitation as a learning process in pathological conditions (Perfetti, 1981). It is a type of approach that consists in proposing to the patient a cognitive task that he must solve through a specific sensorimotor behavior, significant for the purpose of recovering the function.
The method is considered a systemic approach in which the body is seen in its entirety, not intended as an analytic sum of elements, but as a structured set whose properties derive from the relationships of the different elements, but as a structured set whose properties derive from the relationships of the different elements and which are defined as emergent properties. The body moves thanks to the properties that emergent from the organization of the individual elements that compose it. Perfetti considers it wrong and impossible, in a motor behavior, to dissociate the information side from the motor side because, to obtain motor learning, it is necessary to use the most aware and precise information possible. In fact, the movement is seen as originating from the need to give an interpretation of the realities with the system must enter into relationship.
From these premises derives the scaffolding of the exercise, in fact the patient must be placed in a situation in which he has the task of extracting certain information from the surrounding environment, to obtain which, he must try to organize relationships between himself and the environment.
To build these relationships between the environment and oneself, it is essential to activate muscle contractions whose sequence must be characterized by a correct coordination and a good interaction hypothesized with the intended purposes. It is the cognitive situation that must be programmed with linguistic and extra-linguistic means such a way as to require the subject to organize a very specific action considered significant for a correct recovery.

Neurocognitive theory principles

- The body is a receptor surface capable of giving meaning to the world, processing information of various kinds: tactile, kinesthetic, pressure, visual, acoustic, friction, weight, etc. In human action, the norm is to integrate the different information modes constructed. Each action is an act of knowledge and as such involves the construction of information and its integration. The information is not already present in the acting subject and not even in the object. It is the interaction between the subject and the object that allows the construction of an information rather than another that is selected according to the intentions of the subject.
- Movement/ action is the means for knowledge. The body is fragmented in order to know and the fragmentation of the body is linked to the intention and need for information. Muscle contraction represents the last link in a complex process(action) implemented by an intentional system that interacts with the environment, according to its needs, giving meaning to this interaction in its physical and relational meanings.
- 3. Recovery is a learning process in pathological conditions. It is through the learning process, i.e.the activation, with certain modalities, of cognitive processes such as perception, attention, memory, motor image, the resolution of problems that the plastic biological changes occur at the level of the nervous system. Central. In the case of the healthy subject we speak of learning, in the subject with pathology we speak of recovery.

This method uses therapeutic tools that mainly involve the cerebral cortex in order to make the patient learn about the behavioral change that can be achieved during the treatment. In fact, Perfetti speaks of cognitive therapeutic exercise that tends primarily to recreate evolved motricity patterns in the patient and then automate them to form a new motor experience in the patient that is realized following the sum of subsequent operations such as: observation, exploration and comparison.

2.3.3 Benefits of climbing

Physical aspect

Climbing allows to experience more than one form of communication problem and can be helpful for people who have brain injuries (depending on the areas of the brain affected and the severity of the injury).
During climbing, key moves are learned and repeated constantly. This activity also encourages neuroplasticity, since repetitive motions help the brain reorganize its neutral pathways.
Rock climbing promotes:

- hand-to-eye coordination
- problem solving
- awareness of balance
- physical strength
- sensory awareness
- communication

Mental aspect

Rock climbing is a physically and mentally demanding sport. Many climber surveys and psychological researches all point to mental strength as the most influential factor in whether a climber succeeds or not. The cognitive aspect of climbing is rooted in the climber's ability to analyze a surface of a technical route and plan a strategy that maximizes one's movement efficiency. This is based on individual climbing style, ability, and body type.
According with the study made by Pezzulo G et al., climbing experience can help the climber choosing a good strategy, familiarity with a certain route is associated with decreased of anxiety, while a climber with confidence in his own abilities is more likely to succeed.
Memorizing beta and overlearning a sequence, are methods that are often used in climbing. Indeed repetition, practice, and drills improve performance by changing neural connections.

2.3.4 Climb as rehabilitation

The physiotherapist stimulates cognitive and motor learning by physically assisting the patient in "problem-solving", that is in the active process of solving the problems proposed from time to time: he helps him in controlling his posture, in carrying out the movement, in maintaining 'equilibrium.
Fundamental concepts of this method are based on the balance, understood as balance and adaptation of the body to external perturbations; on the role of sensory and feeling systems (visual, vestibular, tactile and proprioceptive) which integrate and influence movements; on the well-being of peripheral tissues based on good physical activity; on the space / environment dedicated to the physiotherapy session and to the people participating.

It is important to vary the environment and carefully choose the functional task to actively stimulate patient participation. This method exploits the stages of neuro-development and neuronal plasticity in response to the stimuli provided by different activities in different environments.
According to the study “Effect of Long-Term Climbing Training on Cerebellar Ataxia: A Case Series“ by Stephan Marianne Anke et al., climbing training has the potential to serve as a new rehabilitation method for patients with upper and lower limb ataxia. The data obtained by this study support the suggestion that long-term coordinative training improves motor performance and reduces ataxia symptoms in patients with cerebellar ataxia.
Furthermore, the fact that improvements occurred in upper as well as in lower limbs goes in line with the suggestion that climbing training is a suitable method to train the whole motor system.
Now, there are a lot of experiment showed that ordinary training, sports for the disabled, being out together with non-disabled persons can, not only help the disordered children with their physical aspect but also help them on their mental area, such as, increasing self-confidence
In recent years, there has been some interest in the therapeutic use of rock climbing as a treatment for depression, but few published studies.
Katharina Luttenbergerresults et al. studied indoor rock climbing (bouldering) as a new treatment for depression.
The results indicate positive effects on the measures of depression. It has been found that depressive symptoms can be reduced on average by 6 points on the BDIII by applying an 8-week bouldering psychotherapy program.
These findings provide the first evidence that therapeutic bouldering may offer an effective treatment for depression, but further research is still required.

3. User research

3.1 Interview

3.1.1 Basic information

Climbing is ideal especially for the recovery of children with Hemiplagia, in the recovery of the upper limbs. They must have a mild degree of disability, without the presence of imprisoned or totally closed hands. To have a more precise reference on the MAC scale, the ideal would be children with a degree of disability 1-2-3; while taking into account the Gross Motor 1-2 level scale. They must have a good cognitive level and in case of visual disturbance it must be quite compensatory.
The interview took place at 10th of July, 2020 with physiotherapist Francesca and Illaria. And the target of the interview is to verify if the climbing sport can really benefit children or not, and ask the advices from the point of therapists.

3.1.2 Questions and answers

Therapeutic aspect:

Q: Does the climbing sport is suitable for the children with CP?
A: Climbing encourages the child to carry out the exact opposite movement, therefore it could be stimulating and therapeutic.
Q: Does it make sense to involve diplegic children?
A: They might be able, but maybe they would need a support: one foot on the wall and the other resting on a fixed stool.
Q: How to stimulate the opening of the hand? What is the main difference when children with CP take things? What are the exercises to encourage the child to open his hand and stimulate opposition from the thumb? What are the ones that the child can do independently, or with whom he has more confidence?
A: Two-hand activities: which encourage the opening of the hand such as: holding the sheet in one hand, while drawing with the other, playing with the ball .. Exercises in which the child's intention is actively.
Aspect to be stimulated with climbing: active intention of the child.
Presenting GOALs to the child is always a positive factor.
Q: Is it better to work on the single movement in a repetitive way or to propose a path?
A: Memorizing the movement trains, and it is very useful, but at the same time offering the child a different path, changing the grips to touch, represents an extra stimulus.
Climbing, especially at the beginning, is a sport that could create a sense of despair, and requires a lot of training before reaching the set goal. Creating intermediate goals helps the child become aware of himself and gratify him, in the same way the presence of physical support could be essential for the first approaches to climbing a child with CP.
The rope element remains an essential factor especially at the beginning, when the child is not yet autonomous in climbing. Subsequently, you can think of eliminating the rope and making it run freely, as long as there is the presence of mattresses.
It is certainly necessary to test how the child behaves in the horizontal gait.
Q: Is it better a wall with few sockets with few paths to avoid confusion for the child or a wall full of sockets to guarantee support at different levels?
A: Better to take several close to help in diversity.
Normally, in vertical climbing the

dominant side prevails and helps the weak side. In the case of horizontal gait, at the level of the route it is perhaps less difficult to advance towards the deficit side, in order to support the weight in advancing with the strong side.
Q: Which of the 3 phases: observation, exploration and comparison is it better to pay more attention?
A: The first phase could include a more perceptive work, putting the two sides in comparison. Closing my eyes I invite the child to become aware of the wall, taking into consideration the textures of the different sockets, the distance of the hand from the body ...
Give preference to hard materials, and go to customize the surface treatment of the sockets.
Balance exercises: psychomotor path for example: going inside circles, keeping a straight station, balance on one foot only on unstable surfaces like a carpet could be. Lateral gait, cross feet, play with the ball with one foot in front of the other.
How to stimulate perception:
Different surfaces are asked to close their eyes and touch the surface first with the paretic hand and then with the healthy hand. Once the child has become familiar with the climb, a small stretch can be asked with his eyes closed. From experimental.

Equipment aspect:

Q: They are admitted to or have to use assistive devices such as orthotics and batten? If not, why not? Could they help?
A: Climbing shoes may not be tolerated by children with CP because they are too narrow and have a particular shoe.
For the feet, large sockets are preferred, the child can also wear his sneakers with the brace if he is used to wearing it.
As for the hands, however, the brace could be an obstacle, limiting the sensitivity and perception of the hand.
For those with a flexed wrist, however, the brace could help him to open his hand.

Participatory aspect:

Group activities:
Looking and suggesting is stimulating.
During the camp the goal is to get them out of the idea of comfort, to stimulate them.
Q: Inclusion of parents in the activity?
A:It could be an incentive, but only a few times, thinking for example of making them climb on the same path. It can be taken into account as an activity to be proposed in the project.

3.1.3 Conclusions

Indoor climbing is a really good sport for the children with cerebral palsy to rehabilitee. It is a useful exercise because it stimulates the pronation-supination of the wrist, the pocket hold can help stimulate the opening of the hand, the horn shaped holds can stimulate the opposition of the thumb. What's more, watching and imitating the other allow them to improve attention ability.
However, the normal indoor climbing sport maybe not suitable enough. Because of remembering the color and the grip to take already requires a significant mnemonic level, some shape of hold might be quite challenging for the children with CP and the lower limb also need to be stable enough.
What we should do is to maintain the simplicity of climbing, designing a new hold that can allow the hand to be closed. Stimulating another movement, extension of the elbow and the supination of the palm of the hand: it is possible to stimulate it with the grip from below. And creating healthy competition during the activities.

3.2 Workshop

This part collects the material produced and the activities carried out relating to the Accept project carried out in period between July and August 2020.The goal is to explain the activities and tools produced by the Design team in the exploration phase of Accept project.

3.2.1 Background

The information in this part is the result of one preliminary analysis phase, with the involvement of everything the research team and partner FightTheStroke, followed by a desk research and validation of the collected data through interviews with experts (Physiotherapists and instructor climbing).
On the basis of the results that emerged, goods were defined specific design requirements for children with CP, focusing on the ergonomic and anthropometric aspects, which allowed to organize the workshop and the activities described in this report.
The workshop had, mainly, the objective of share and validate some of the project requirements highlighted in the research and co-design the experience of climbing. In particular, specific objectives were:
tactile experience and cognitive engagement. Routes preparers for climbing, observation of companions - pre activity
Route (how to place the sockets) and type of taken - during the activity
Incentive to carry out rehabilitation activities correctly: eg. incentives and rewards for children, objectives to be achieved, et ..- post activity The workshop was organized by the Design team.

Date: 22 July 2020

Place: red room of the Department of Design

Participants:

Alessandro Colombo (DEIB), Francesca Fedeli (FightTheStroke), Giorgio (Department of mechanics), Vittoria Roiati (TTO), Rolando Brandolin (DEIB) Giovanni Piras (Rockspot instructor), Marita Canina (Design).

Design team facilitators:

Carmen Bruno, Chiara Parise, Rui Zhang

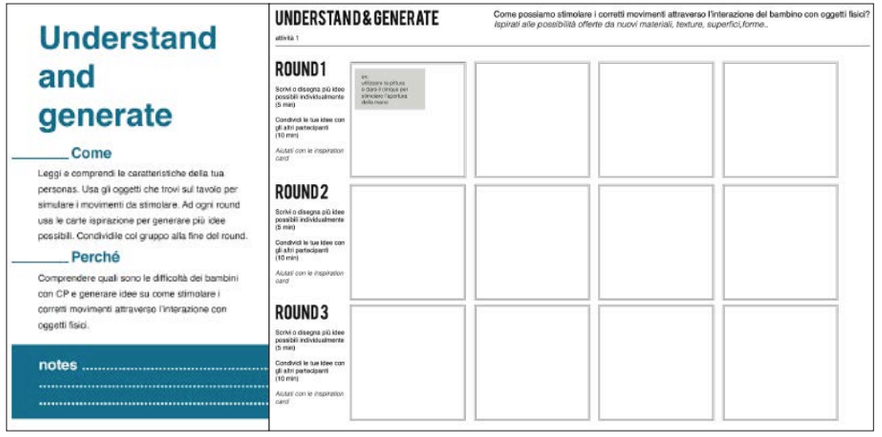
3.2.2 Structure of the workshop

The information in this part is the result of one preliminary analysis phase, with the involvement of everything the research team and partner FightTheStroke, followed by a desk research and validation of the collected data through interviews with experts (Physiotherapists and instructor climbing).
On the basis of the results that emerged, goods were defined specific design requirements for children with CP, focusing on the ergonomic and anthropometric aspects, which allowed to organize the workshop and the activities described in this report.
The workshop had, mainly, the objective

Activity 1

UNDERSTAND AND GENERATE
The goal of the activity is to generate ideas to stimulate certain movements through the interaction of the child with physical objects that can have new, new forms materials, new technologies.
To empathize with the target audience and understand his disabilities and motor difficulties were distributed the personas tools with some specific indications collected during the primary research. Different objects have been arranged in the center of the table nature including sponges, handles, stress balls, sticks and rubber bands to stimulate the participants and try to repeat the movements illustrated in the personas.

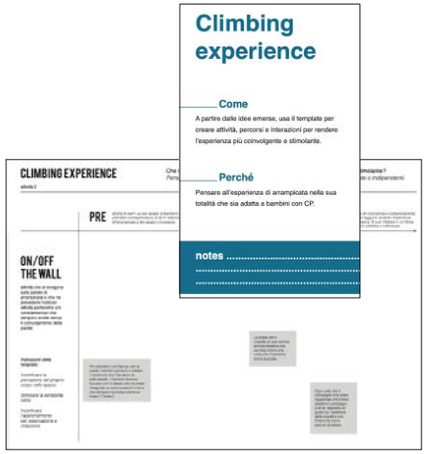
After 5 minutes, participants were asked to generate new ideas collaboratively on possible interactions of the child, taking into account the different difficulties e disabilities presented in personas.
Aided by a specially designed template, they are 3 rounds of 15 minutes were scheduled: 5 minutes for each round to write and draw ideas individually and 10 to share your ideas with other participants. At the time of sharing it was also possible try to improve ideas presented by other participants or add new ideas based on your own needs personas.
In the absence of ideas / inspiration, in the center of the table I am have been made available to inspirational cards: cards with some images that can help generate new ideas.



Activity 2

CLIMBING EXPERIENCE

The goal of the activity is to build activities, paths, interactions, etc .. suitable for children with CP, which they can be integrated into the wall or used in independently, in order to make the experience of engaging and stimulating climbing for the child.
Starting with the vote of the ideas most appreciated by group in the previous activity, was asked to build activities thinking about the characteristics of the 3 moments of climbing (pre, during and after) and the fact that it can whether or not there is interaction with the wall.



RESULTS: IDEAS EMERGED

The participants immediately showed enthusiasm and creativity in generating new ideas. In particular, many design ideas emerged. It would be interesting to work for thematic paths, that is to plan paths adaptable according to the types of sockets and objectives to be achieved, making children feel the protagonists of a story. In this regard, the climbing instructor reported some of his experiences as a treasure hunt on Halloween or Christmas theme wall.

Another idea that emerged is to create paths for associating perception: they are installed on the wall taken with different textures that suggest to the child correct movement. Some outlets may present more textures, for example a tubular circle in which you

interspersed with textures with different finishes.

Some hypotheses

In order to stimulate cognitive learning the activity could be divided into 4 different phases:

- I observe others: the child compares himself to others (particular attention must be paid to comparison which must be challenging but achievable).
- I visualize the movement: the child closing the eyes try to visualize the movement / path just observed.
- I put into practice: climbing or realizing the movement planned.
- I practice: together with another partner.

During climbing there is a continuous bending of the pelvis, to shift the weight from one foot to the other, the flexion of the pelvis to always keep the arms straight and make less effort.

Also, keep in mind that children present sensory limits, do not like the feeling of dirt and wet, they have a minimum level of tolerance. The same goes for the noises some children present a low tolerance of loud noises, such as the drill can remind them of operations and represent a trauma

3.2.3 Results

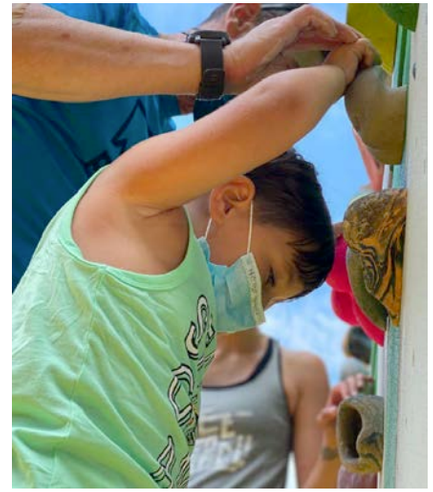
The workshop was successful as they emerged ideas and suggestions that have been concretized in activities to be carried out in the climbing experience.
Following are the activities divided into:

- integrated activities, to be carried out in the first phase of warm up and introduction to climbing
- wall exercises, to stimulate and involve the child in the climbing stage

3.3 Fight camp

3.3.1 Background

The fight camp is a camping activity in the summer of 2020 to test the children with CP in real and figure out if they are suitable to regard the climbing sport as a therapy treatment or not.
During the construction of the climbing wall, the instructor or volunteers are asked to integrate activities to test some of the ideas that emerged during the workshop.



3.3.2 Activities and the targets

Exercise off the wall

Bucket and materials:
Procedure: ask the children to dip their hand into the bucket and open their hand to look for a key or other object
Material: 3 buckets, one full of water, one full of sand and the other of a gelatinous substance.
What to observe:
Do children show willingness to carry out the activity?
If not, what is the poorly tolerated substance?
Are they able to open their hand in the different substances? Do they ask to repeat the activity?
Do they do it to achieve a goal?

Follow the textures:
Procedure: the child is asked to perform a path on the wall using only the upper limbs, not involving the feet. It is also possible to carry out the activity with your feet on the ground, asking the child to close his eyes and try to follow the holds with the same texture.
Material: taken with different textures and finishes.
What to observe:
Does the child recognize the difference in the different holds? Despite having different colors?
Can the child perceive the differences between the textures even with his eyes closed?
Does the child show himself involved in the activity or bored?

In what form:
Procedure: the child is asked to grasp grips (handle grip; horn; pocket; ring; bowl, etc.) to which a different material will be added in a specific point (e.g. sponge on the back, threads of wool in the lower part, etc.) on the wall using only the upper limbs, not involving the feet. You can also carry out the activity with your feet on the ground, asking the child to try to reach the different material by rotating, opening or making other movements.
Material: taken with the integration of different materials.
What to observe:
Can the child perform the movements useful for rehabilitation?
Which grip invites the child to make the correct movements?
Can the child perceive the differences between the materials?
Does the child show himself involved in the activity or bored?

Follow the fabric:
Procedure: as in the previous exercise, the child is asked to follow the path dictated by tactile perception. In this particular exercise strips of fabric, ropes (or other) are hung on the wall and with eyes closed the child tries to follow the path with his hand (first with the hemiplegic one and then with the healthy one).
Material: fabric strips and double-sided tape
What to observe:
Does the child recognize the fabric on the wall? With both the hemiplegic and the healthy hand?
Does the child open his hand to follow the path?
Is the child enthusiastic?

Draw your hand
Procedure: the child climbs horizontally, at the end of the wall he finds a sheet stuck on the wall and he is asked to draw a smile with a marker, or to dip his hand in the paint and draw his own footprint on the sheet.
Material: white sheets, paper tape, tempera and markers
What to observe:
Having a final goal, does the child carry out the climbing activity more actively?
Does he show refusal to put his hand in painting?
Are you able to open your hand and hold the marker independently? /
Can you open your hand fully to draw your footprint?

Mirror
Procedure: To familiarize themselves with the movements, it could be hypothesized that children who do not climb have the possibility of simulating the sequences on a floor that reproduces the setting of the wall (a sort of twister). In this way it is possible to stimulate other types of muscles and help the child to get into climbing without immediately being on the wall, thus reducing the impact that this discipline causes the first time you try it.
Material: sockets printed on sheets of paper
What to observe:
Does the child remember the hold and the sequence to be simulated?
Does the child use the correct limb for each grip? In particular, to involve the weak limb in the activity?
Show movement skills in floor sequence simulation?

Feet to the ground
Procedure: The activity focuses on the use of the upper limbs. The feet are kept on the floor or possibly on steps whose dimensions favor walking. The hands instead will have to follow sequences of different tricks as you advance horizontally. This activity can be introductory and bring children closer to this world, while simplifying the climbing activity. In this way, all attention can be focused on the rehabilitation of the upper limbs.
Material: -
What to observe:
Does the child remember the sequence?
Does it show involvement in the activity?
Do you perform the movements as suggested by the therapist / instructor?
By involving both hands?
Does the child try to take the furthest outlets? Does it extend the elbow?

Exercise on the wall

Mime in pairs
Method: children are divided into pairs, taking into account their respective physical and motor characteristics. Children climb in turns and each time they climb they are asked to use the holds used by others and to add an extra movement and consequently an extra hold. The feet are free. Basically the circuit is created by the participants themselves and is repeated several times from the beginning.
Material: -
What to observe:
Is the child able to memorize the holds and the route taken by the previous partner?
Does the child show interest in playing the game?
Does the child tend to use only the healthy limb?

Tell a story
Procedure: Using sockets with a specific shape can help the child memorize a narration that facilitates the learning of the sequence. This activity can also involve other children, who can be the creators of the story itself or carry out different activities such as drawing the shapes or telling the story to the child while climbing to suggest the passages.
Material: Sockets can be numbers, letters, geometric shapes, animals, natural elements or reproductions of objects.

What to observe:
Does the child listen to the story told by his peers?
Does the child show enthusiasm in carrying out the activity?
Do children not involved in the climb show attention and cooperation?

Direct-indirect
Procedure: In a first phase the child is shown (direct teaching) which movements to perform and which holds to use to reach a hypothetical goal (top). These will be studied and designed according to the rehabilitation to be offered. Then the child is left free to reach the same top using the movements and holds he prefers. This will allow us to verify if it instinctively reproduces the movements previously shown and therefore if the rehabilitation is effective.
Material: -
What to observe:
Does the child instinctively reproduce the movements shown above?
Does the child show creative ability to find new paths?
Does it show ability to stimulate both limbs?

Team relay
Procedure: the children are divided into teams. One child per team must reach the top of the wall and jump down to give his teammate a high-five who will then set off to climb the same route. The team that finishes the round of all the children in the shortest time wins.
Material: -
What to observe:
Do the children show themselves to be participatory and stimulated by team activity?
Is the child who climbs able to climb vertically independently and without a rope?
Is it dangerous to have children jump on the mattress once they reach the top?
Do children who wait their turn show cooperation and encourage their partner in a positive way?
Does the child who climbs become distracted during the climb by his companions or by the children of the other teams?
Does cheering on your own team confuse the child?

Relay race with flags
Procedure: the wall is divided into two sides by a paper band. On the wall there are bandanas / pieces of cloth stuck near some sockets. The children are divided into two teams; one at a time they have to climb and to collect the largest number of flags.
The activity can be carried out in time: each team must move the largest number of flags on their side of the pitch by sticking them to the grips with Velcro. The team that has the most flags in their field when time runs out wins.
Or it can be carried out in a classic relay race in which the flags are detached from the wall and brought to the ground. The team that has collected a greater number of flags at the end of the flags on the wall wins.
Material: bandanas or pieces of fabric, paper tape to mark the field on the wall.
What to observe:
Do the children show themselves to be participatory and stimulated by team activity?
Can the child climb and pick up the bandanas? And to transport them to the other side of the field?
Are you using your weak hand to pick up the flag? (could be placed as a constraint)
Does the child who climbs become distracted during the climb by his companions or by the children of the other teams?

Dodgeball
Procedure: one child at a time freely climbs the wall horizontally. Children on the ground can use a sponge ball to try to hit the child on the wall. If he is hit before he reaches the end of the wall, he loses and must give way to the other children.
This activity can be done in teams: each child who reaches the end of the route brings a point to their team and children on the ground can protect their climber by defending the wall.
Material: sponge ball - white and red tape or chalk, to delimit the defense area from the attack area.
What to observe:
Can the climber keep his concentration on climbing?
Does the ball create too much confusion and is a risk for the climbing child?
Do the children show themselves more involved because they belong to a team?
Are all the children involved in the activity or is someone excluded from the game? Because?

The ideal holds

The research and interviews revealed which movements could be stimulated during the climbing phase:

- Hand opening
- Thumb opposition
- Supination of the hand
- Elbow extension
- Heel flexion

In order to make climbing a useful exercise for rehabilitation, it is necessary to maintain the simplicity of climbing, that is, to rely on the rules of balance and climbing techniques, while maintaining a simple and intuitive path.
For this reason, it is necessary to prefer large grips in order to stimulate the complete opening of the hand and to prefer a spherical surface with a large grain to ensure greater grip.
Among the existing grips, the pocket grips certainly help the child to cling using all the strength of the hand, while the horn grips are positive since they favor the opposition of the thumb.
In general, grips are preferred over supports, since the grip allows the closing of the hand and one and guarantees greater safety for the child.
Another movement to stimulate is the extension of the elbow and the supination of the palm of the hand: it is possible to stimulate it with the grip from below.
During climbing it is necessary to stimulate the lower limb: stimulate the weight on the leg to ensure stable support.
In particular, as regards the reference target, the difficulty could be even greater. For this reason it is good to ensure that the sockets dedicated to the lower limbs are simplified and have a semi-horizontal surface.
As for the movements to be stimulated, in the specific case of children with CP it is better that the position of the foot sees the heel pointing downwards.
In summary, if there is a possibility, it would be advisable for the wall to have the following sockets installed to try to stimulate the movements identified in the research (hand opening, thumb opposition, hand supination and elbow extension):

- handle grip
- horn
- pocket
- ring
- bowl

with different textures: to try to simulate the path by tactile association, sockets with different grain can be installed, taking into account that sockets with a greater grain are favored to ensure greater grip.

3.3.3 Result

The climbing activity was particularly appreciated by children, arousing interest, resourcefulness and inclusion by all members of designated groups.
An improvement was seen over the course of the week by practically all children. Part of this improvement is due to the introduction of the rope as support tool that has improved the confidence of children in tackling the path of the wall.
The first few days the boys tried climbing horizontally without rope. It was their first approach to climbing and despite some difficulties in being able to hold on for more than a minute, they showed great spirit of initiative and enthusiasm especially in activities in which they were asked to achieve goals: peas hidden among the sockets o a water gun positioned at the highest point of the wall.
When the rope element was introduced, the children tensed much to weigh on the rope, while towards the end of camp many children faced the ascent without weighing themselves
on the rope, which was used only in some cases such as maintaining the position and in general only as a security tool. At the end of the camp, one of the children with a hemiplegic hand he managed to climb the whole wall completely bandaged.

During the Camp some members of the Accept team have got to interview physiotherapists and experts from climbing. Some assessments emerged as to how much concerns the types of sockets installed on the wall:

- the pocket sockets were found to be positive as encourage children to put their hand in the cavity, especially for children with a very stiff hand;
- the rounded grips are the preferred ones because allow you to rest your whole hand on it;
- drip grips / reversed grips were well used after a brief explanation of the instructor;
- the pliers and hexagonal sockets instead have presented difficulties in use.

4. Ideation

Ideation

4.1 Persona

Base on the information I have collected during all the research part, the users of the climbing hold has been chosen, and in the following part I am going to conclude all the characters into one persona to help me have empathy with the users and understand the needs better.

4.1.1 Information

Federico (M), 6-year-old with spastic cerebral palsy of MACS level III, which means he handles objects with difficulty, such as, it is difficult for him to move coordinatedly and keep balance; it is hard for him to manuplate small things such as picking beans. Besides the movement difficulties, he has comprehension problems and tactile registeration difficulty.

4.1.2 Needs

- Being encouraged
- Having a domestic therapy.

4.1.3 Wants

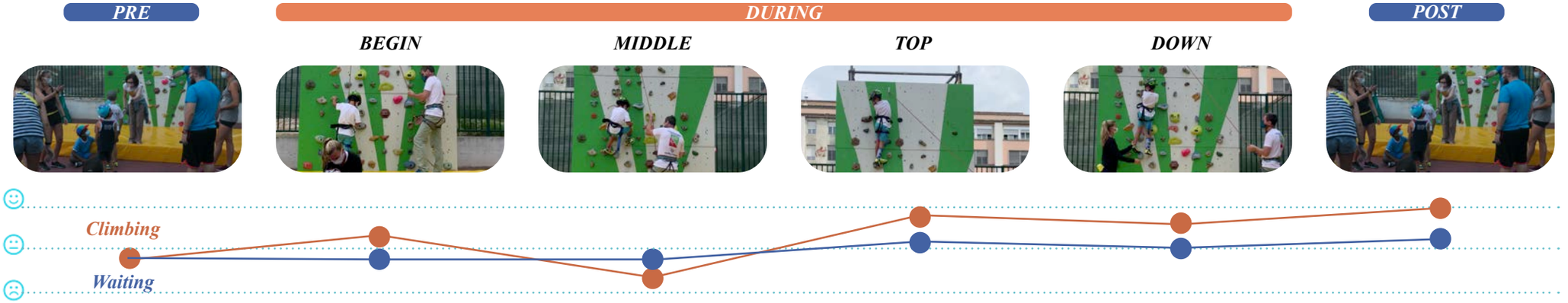
- Build confidence
- Get affirmation from others
- Climb to the top of the wall

4.1.4 Frustrations

- Strange physical therapy
- lack of confidence

4.2 User journey map

Setting the camp as a reference, creating a user journey map can really help me understand the different needs of the persona in different phases of climbing.



	BEGIN	MIDDLE	TOP	DOWN	
Meet a lot of children, feel depress because of the strange enviroment and people. Have nothing in common but illness. Feel afraid about the climbing.	After encourage by the coach, set up the mind to take chanllage and really want to reach the target (cross the wall horizontally, climb to the top, touch the water gun) Feel bored when it is not the turn.	The hold start become smaller and smaller and the strength is going to be run off, feel sad and don't know what should do next, but still want to complete the chanllege.	After reach the top of the wall, feel exicting and gain the confidence	Still exciting because the others are prasing me, but there is nothing to do but let the coach release the rope slowly.	Feel happy and can't stop sharing the experience to the other children and encourage them to take the challenge. Want to remeber the feeling.
PAIN POINTs					
• A sense of alienation from a strange environment and the other kids • Afraid of climbing because never take it.	• Can not pay much attention on the climbing kid.	• Some of the holds is too small to stand and grab • Lack of energy	• After few times the child gets bored		• The process is too short to build effection • Language barries to share the experience and emotion
OPPORTUNITies					
• A climbing product that every one has in home and also can be used on the climbing wall.	• Set the hold on the middle as one of the goal.	• Put a really big hold in the middle allow the child to rest or set the hold as a goal	• Put some other thing one the wall to have more interaction.		• The product can allow them to take home or they have the same product, to help the children review, practise, express the feeling.

4.3 Conclusions

After all the analysis I have done, here are three aspects that the new climbing hold can contribute into.

Ergonomic

Creating a grip hold that allows the hand to be closed.

Therapy

Creating a climbing component which can be associating the sensory integration therapy
Creating a climbing component which can be also used at home to increasing the duration of the climbing healing effect.

Excitation

Creating a climbing component which can be also used at home to reduce cognitive difficulty and children's unfamiliarity with climbing.
Creating a climbing component which can be regarded as a small target at the middle of climbing experience.
Creating a climbing component which can provide different activities during climbing, preventing children from getting board.

4.4 State of art

It is a quite new area in the market, in this case, there are none of the product in the market have all the characteristic I mention above.
Below are illustrated some interesting solutions that, thanks to the different technologies and activities they are combining, expanding the boundaries of climbing.

4.4.1 Liberator medical adaptive climbing wall

Liberator medical adaptive climbing wall is a project sponsored by the liberator medical Supply™. This company is a leading provider of catheters & urological supplies, ostomy & diabetes supplies, incontinence products and mastectomy fashions.
The project is presented by Presented by Mark Wellman, an adventure athlete, Paralympian and the first paraplegic to summit El Capitan and Half Dome in Yosemite National Park.
This interactive booth and demonstration shows individuals that not only can they climb the wall, but they get to participate in confidence building, goal-setting and increasing strength and flexibility.

4.4.2 Adaptive climbing wall in Duke university

This project is built in the campus of Duke university. The aim of the wall is to using climbing program to break down barriers and help people with disabilities reach new height in program at Wilson center.
The initiative, which started in October 2013 with one climbing event, has evolved into monthly climbing clinics as interest grew across the Triangle. Now, the founders are encouraging others to start similar programs elsewhere.
And they also think there is a lot of opportunities beyond the wall. In the founders opinion, by climbing on the wall, the people with disabilities will realize that the limitation of the body will never limit oneself and they should be given some hope and courage about facing other challenge in life.

4.4.3 Everlast climbing

Everlast climbing is a play core company, which has been working with educators and youth serving agencies for over 20 years to bring the benefits of school climbing walls to facilities throughout the US. Their climbing walls, along with their hand holds, mats, safety features, curriculum and accessories, will enable children to develop the best possible climbing program.

They believe that climbing provides physical, emotional, social, and academic benefits. With different climbing wall they can help contribute the children to physical, cognitive and social-emotional development and the benefits of climbing for children with special needs.

They also have the adaptive climbing wall and it is named Traverse wall.

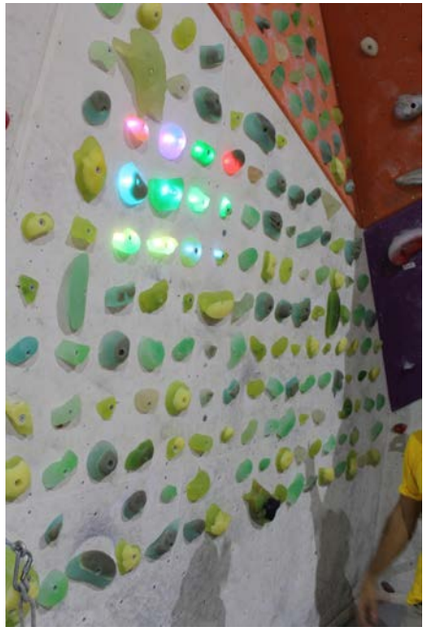
In the Traverse wall, the children are asked to climb horizontally, not vertically. The wall is 8' or 10' high and comes in sections to allow for any desired length. The fun and challenge of a Traverse Wall is making it from one side to the other, rather than to the top. Students are never more than a few feet off the floor as they climb horizontally across, the wall. No ropes or harnesses are needed. Traverse Walls can occupy and optimize a variety of spaces--from gymnasiums to classrooms to hallways.

What's more, the Traverse wall, with its companion activity guide, helps instructors effectively include youth with special needs in their climbing program. The smooth, dry-erase and magnet-accepting surface can be written on and accepts magnets to provide learning opportunities for children with cognitive or communicative disabilities. The Adaptive Holds include grab-bar style hand holds and ledge-style foot holds to provide stability and extra support for children with physical disabilities. The color-coded Groperz™ Hand Holds offer a variety of additional options for climbers to use as they travel across the Traverse Wall. Green hand holds are the largest and easiest to grip. The yellow holds come in a variety of sizes and offer a light challenge. The red holds are medium sized and provide the most challenge. Climbers can choose to use any color hand hold, or try the extra challenge of climbing using only hand holds of the same color. Their signature Red-Relief Line® is a safety feature that reminds climbers to stay within a distance of three feet from the floor and is a helpful tool for the climbing wall supervisor.

It's the ideal climbing wall for adapted or inclusive physical education, occupational therapy and physical therapy and provides opportunities to develop balance, body awareness, muscle strength, motor planning and more. Climbing also provides proprioceptive input to improve sensory integration. The Adaptive Climbing Wall is also well suited for special education classes where learning and movement can be integrated and problem solving, visual attention and concentration are required.

4.4.4 Climbling

ClimbLing aims at enhancing the experience of indoor climbing through an interactive climbing system based on translucent touch-sensitive holds. Each smart hold has a led inside and is connected to a computer.
Through a tablet and an app, users can choose the following modes of climbing:
Random paths: the user chooses e level of difficulty and the length of the path (either number of holds or time) and climbLing generate a random path. The path will light up fully with one color (boulder mode) or 2 holds at a time of different colors (right hand/ left hand) as the climber reaches one of the holds illuminated
Pre-determined: a standard path saved by the gym or by the user can be loaded and repeated. Also here, the path will light up fully (boulder mode) or 2 holds at a time
Personalized: the user can create a path by selecting the holds he/she wants to use.
Instruction: an instructor control which hold to light up while the learner is climbing on the wall
Gaming: kids can play different games built in the app. The games available for now are Pacman, Memory and Red light/Green light
All of these ways of climbing can be supported by light only, or light plus sound in case of visually impaired climbers.
While the climber is on the wall, the system measures the time spent on each hold as well as the time to complete the overall path. Each climber can download a personal app which will keep monitored the climbing activity and provide statistics on both climbing activity as well as an evaluation of the climber level, including parameters like strength, endurance, constancy, and speed, as well as a synthetic climbing grade, continuously updated based on new climbing sessions.



4.4.5 Valo motion

Valo Motion is a game developer and hardware manufacturer based in Finland. Valo Motion revolutionizes how sports and games are combined to create fun and effective exercise. We believe that high quality products should be developed with smiles and passion for sports & games.
The name Valo Motion comes from the Finnish word valo, meaning light, which is central to our products.
ValoClimb® is the world's first augmented climbing wall that comes with several interactive games. Games contain dozens of modes and plenty of different levels. Game selection covers single and two-player games, including the viral sensation Climball as well as Shadowlings, a game which interacts with the climber's shadow!
This interactive game platform invites anyone, from the youngest kids to hard training adults, to a have an amazing time and get a great physical exercise. Even the audience is easily captivated by the games. People often spontaneously participate by cheering and shouting instructions.

4.5 Brief

HOW MIGHT WE: Improve the climbing therapy affection and the motivation of children by providing a dedicated hold for the children with cerebral palsy to connect the experience of climbing activity and domestic therapy.

What?

The design of an special climbing hold which can not only use it while climbing, but also can be a toy that motivates child to play beyond climbing.

Why?

Because, in rehabilitation perspective the children need to have the domestic therapy while they are at home, and they can not climbing frequently because of the cost of time, organization, venue rental, etc... but they need to review some feeling during climbing.
And, in extation perspective, children with CP are not motivated by the climbing activity, meanwhile they might be afraid of the excercise since it looks hard to do.
What's more, in product perspective, not all the holds in normal climbing are useful for the children, and there are not yet physical therapy product that can remind the kids the climbing experience.

Who?

The main users of the holds are children with spatic hemiplegia cerebral palsy who is around 6 to 12 years old and need to practice during climbing therapy.

Where?

The hold can be used into climbing gyms and for domestic use.
The hold need to have the normal way to install on the climbing wall.

How?

Using different Curvature and thickness on the shape of the hold to similate different hand opening and closing positions.
Can be used as a toy or part of it to motivate the children to play with it.
Offering a mount which can easily assemble some small part in order to add some other activities on the climbing wall.

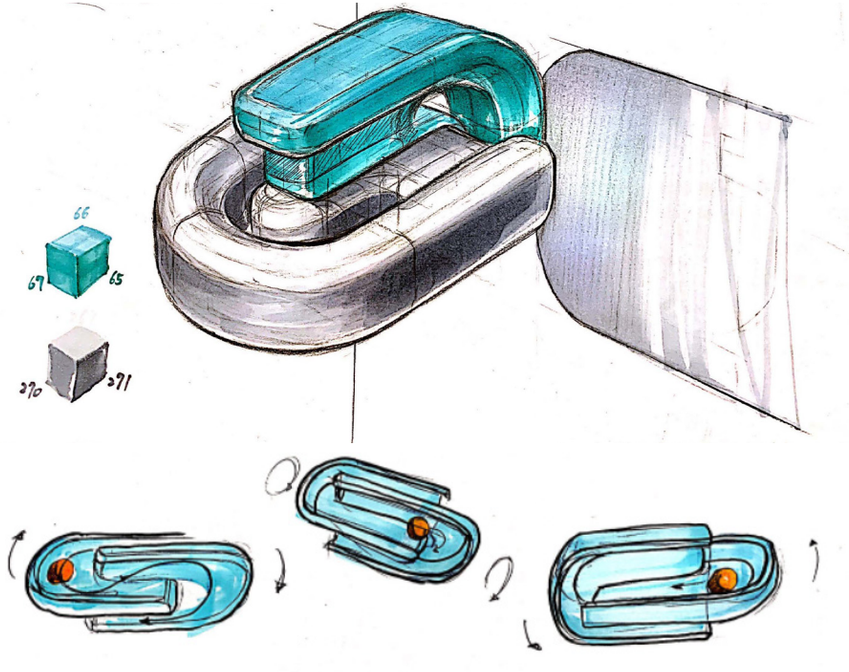
5. Product development

5.1 Moodboard

Wants to have a grip like shape while intergrated some function of toy.

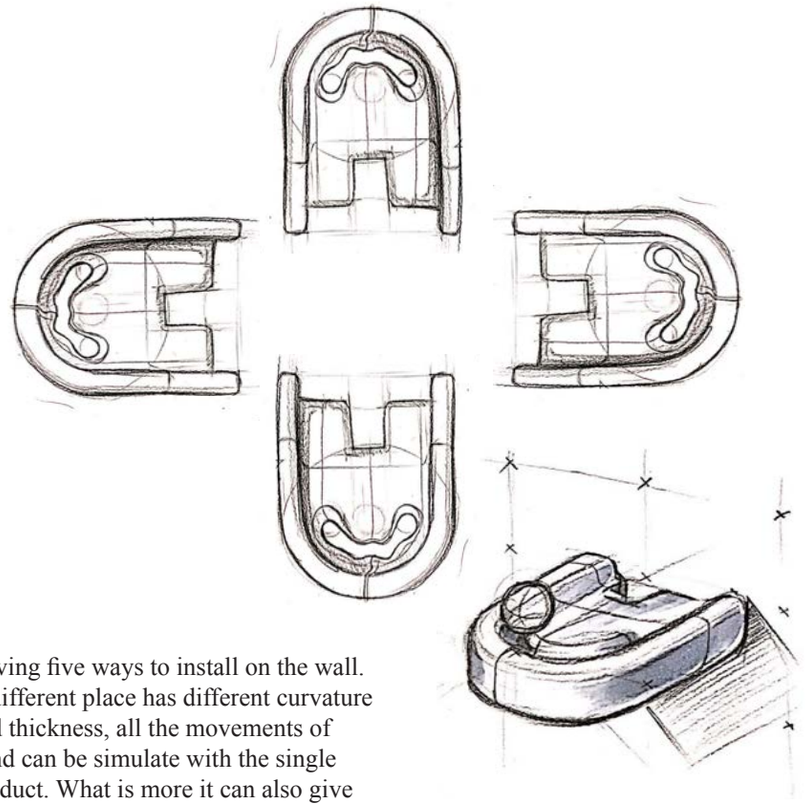
5.2 Concept generation

5.2.1 Concept 1

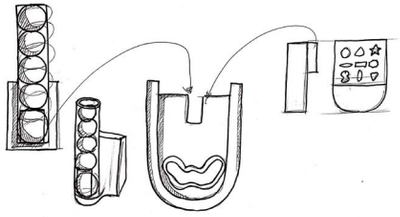


The starting point is that two holds can be assemble with each other and become a toy to play at home. In the toy, the ball can infinitely roll between the gap. Using this toy to motivate children to play with it, in order to have a review about the climbing experience.

Meanwhile, the ball can be intergrated with different texture, for the purpose of making the ball roll at different speed. In this way, children are not easy get bored of it and have more understanding about different texture.



Having five ways to install on the wall. If different place has different curvature and thickness, all the movements of hand can be simulate with the single product. What is more it can also give children a really big plate on the wall.

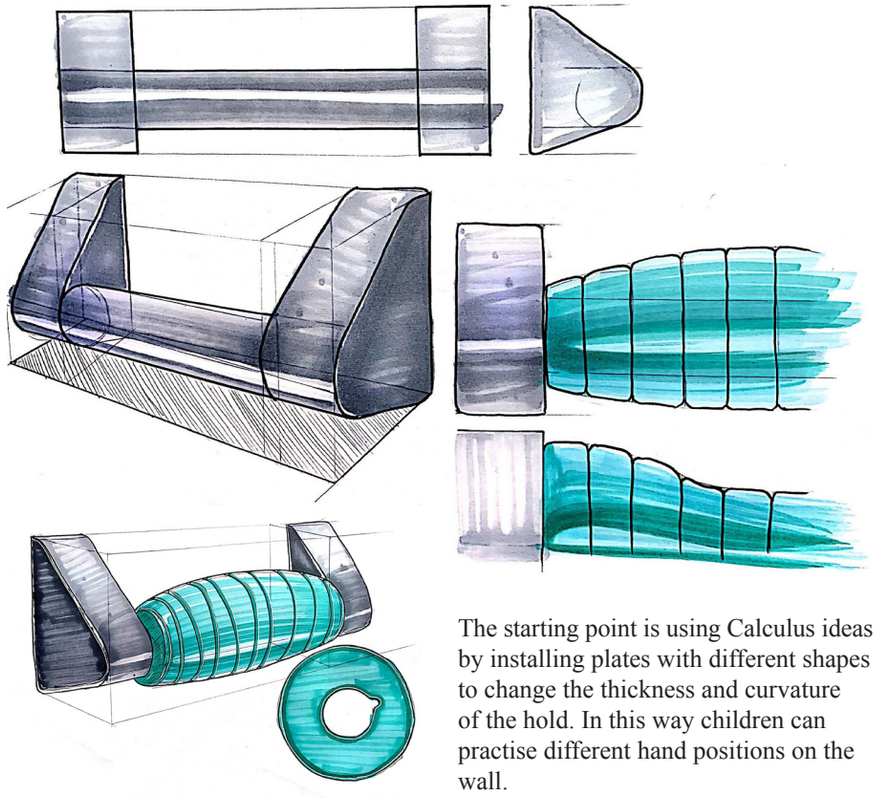


The other accessories can be also designed to provide more activities and therapy on the climbing wall. In order to make the children feel excited.

Feedbacks

The toy and the accessories could be interesting, but the shape is not seem to be easily grabed.

5.2.2 Concept 2



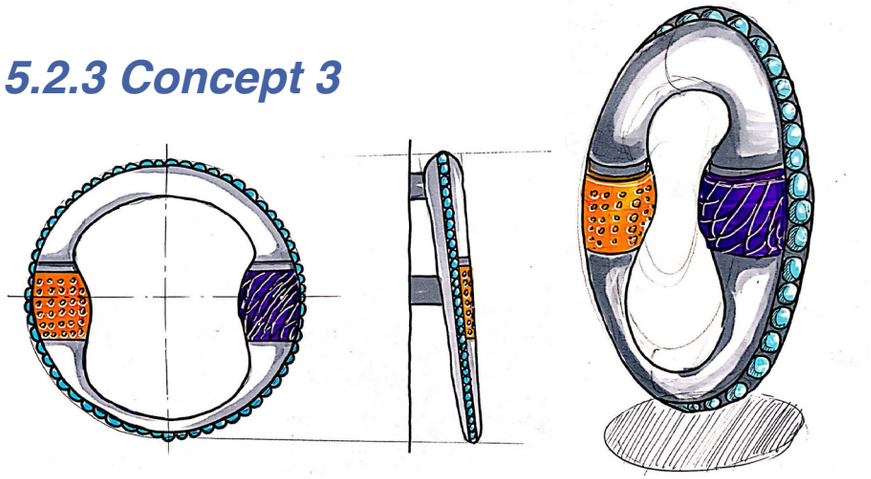
The starting point is using Calculus ideas by installing plates with different shapes to change the thickness and curvature of the hold. In this way children can practise different hand positions on the wall.

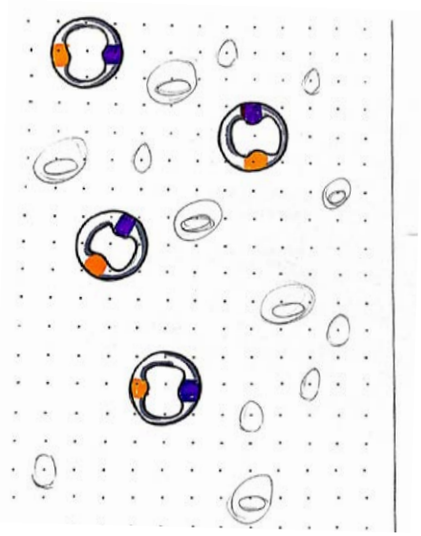
The plates can be used at home as a toy, which can remind the children of climbing. Meanwhile, the different plate has different texture which can help children to have domestic senor therapy.

Feedbacks

Calculus ideas could be interesting, the base on the wall (the grip) is not well designed and the base should be mounted on the wall with single bolt.

5.2.3 Concept 3

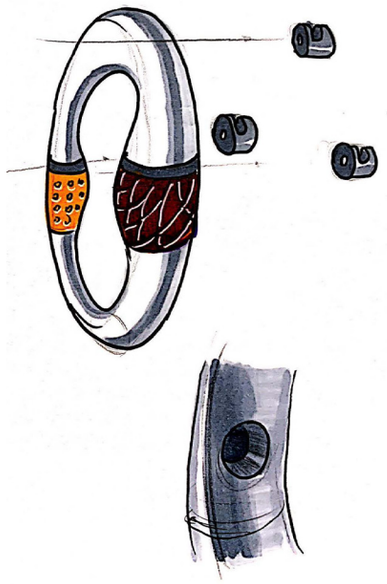


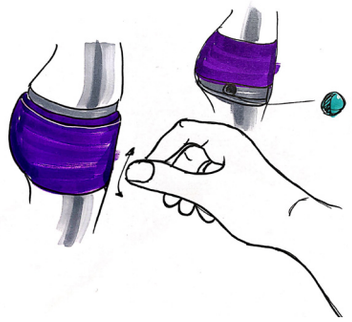


The concept is inspired by piggy bank , which allows the children to collect the award, which should be small balls with different texture and color in this case.

It is basically a shape of the ring, but symmetrically, the shape have different curvature, so as to offer different grabing experience during usage.

The two sides of it have the rubber coating part with different color and texture, which can help the children distinguish the direction on the wall and help them with tactile registration.





It can be installed on the wall with three small holds and the small hold can be alway remain on the wall for the normal climbing,

Feedbacks

The way of excitation and the shape are interesting. But it is hard to assemble on the wall.

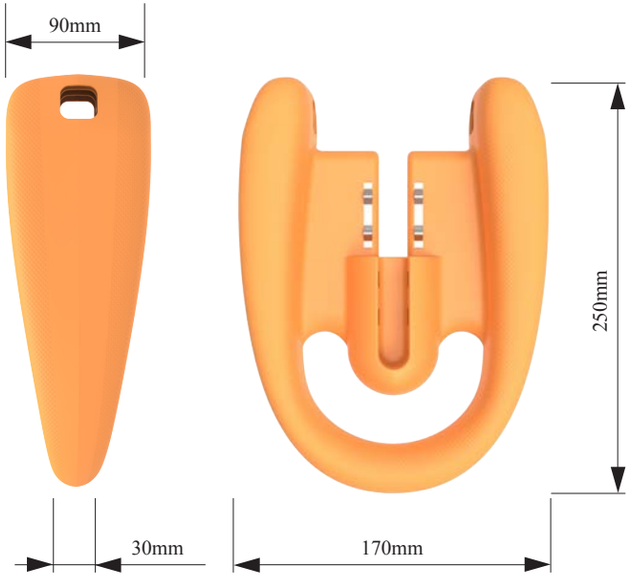
5.3 Concept development

5.3.1 Shape design

Dimension

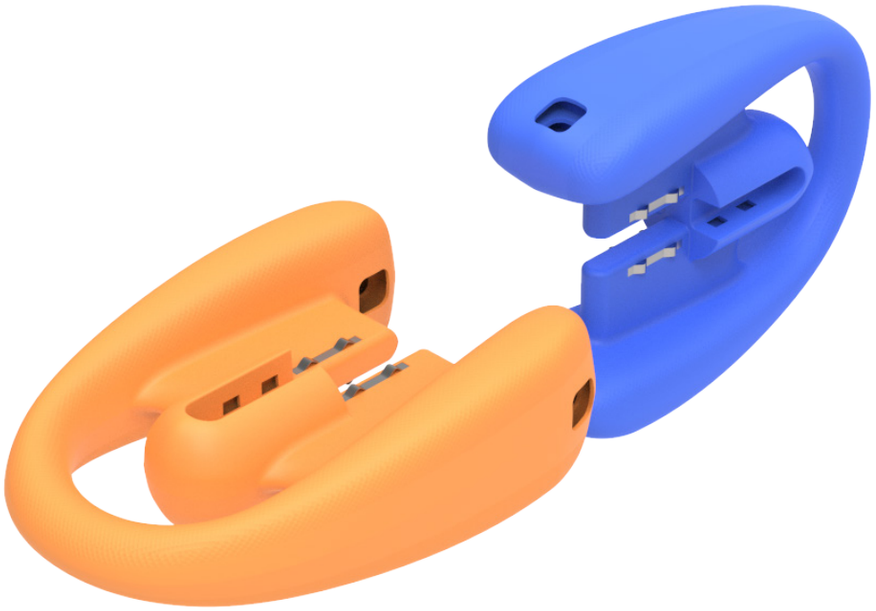
The hold has been designed bigger than the normal hold, because of these:

- The children with Cerebral palsy always overstimate their body size, and they will feel safe when they are using the big product.
- These children have difficulties in the fine hand movement, since the elements of toy and handle are conbined in this hold, as a toy, it can not be so small.
- With different part of the hold, all of the hand positions are integrated, the thickness transitions from 30mm to 90mm to allow the children to have different experience from fully closed to fully opened hand.
- Can be used as a big plate at the middle of climbing to let the children rest and stand stable.
- Can be set as a goal to help the children break the difficulties of climbing.



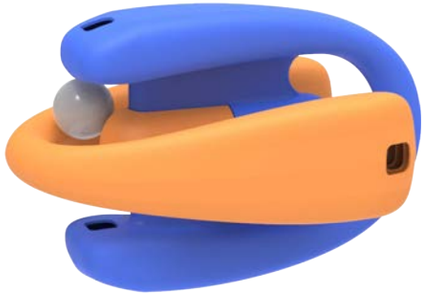
Hand positioning

Different hand positions can be provide by the hold: Open the hand/ Thumb opposition/ Elbow extension/ Hand supination/ etc.
For opening the hand, one side of the hold offers 90mm thichness, which can fill the entire palm of the child.
For thumb opposition, also we can call it close the hand. The grip part has been offered with 30mm thick. The thickness is not too thin to feel not stable, also not too thick. In this way, the children can grasp the tubular part of the product to close the entire palm.
The product can be use both horizentally and vertically, all of the parts on the hold can be grab.What is more, the excess between the thickest and the thinnest size makes different parts of the handle have different gripping methods.



Assemble two of them

The middle part of the holds are designed to connect to each other, the gap can increase the touching area of the two holds, and make the connection more stable. What's more, when the holds are settled on the wall the connect structure can also connect with other activity components.



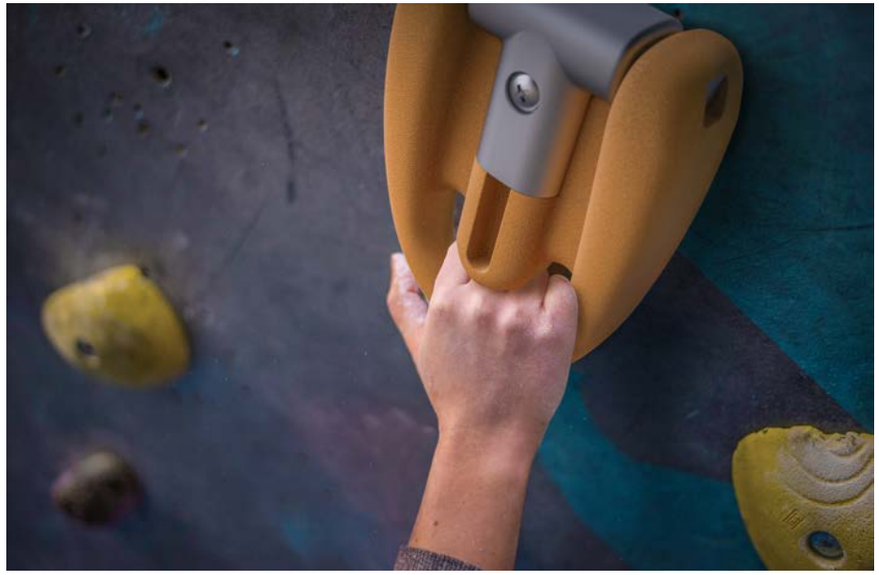
5.3.2 Installation

Mainly, the hold can be installed on the wall both horizontally and vertically. The special component has been designed to link the hold and the wall by offering two different mechanical joints. The mechanism between the hold and the link is a metalic bar, since the hold need a strong mechanism to prevent the bending of the bar itself and avoid rotation of the hold.
The mechanism between the link and the wall is a normal 3/8 bolt, because it is the common assembling technology in the gym. By using the "bolt on" method the hold can be installed wherever the therapist want on the climbing wall.

5.3.3 Usage

Domestic usage

In previous research, we already know that children can get benefit from the climbing by getting a realy good experience, but lower frequency of climbing training leads the training effect to decrease. In this way, children really need a training product which they can use at home in order to help them get emotional connection with the climibing experience.
The product has been developed in this thesis gives this new meaning to children by assembling two products together. As it show in the figure, the children need to keep the balance of the "toy" and let the ball rolling smoothly between the gap by holding different places of it, the route is infinite, so the ball can forever roll along the route. Therefore, inducing children to interact more with the climbing hold through the interactive method of toys is the core of the design of this product. The product has been designed to conclude all the experience of touching the holds on the climbing wall, so the shape deliever this meaning to children by allow them to have the hand position from openning hand to the closing hand. When the children rolling the toy at home, he need to touching everywhere of the hold to maintain the ball on the hold, so all the experience will be reviewe. Next time when they go to the gym to practise, they will recoginize the hold on the wall first and when they start to climb, they wall find all the hold is familiar.



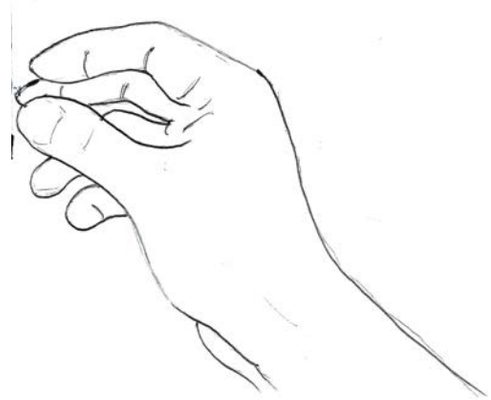
Usage in the gym

In previous research, The shape of the hold has been recommonded by the therapist— the grip shape. So the most important usage on the wall is helping the children to practise closing hand position by offering them a tube shape part.
In this way, one of the usage on the wall is that the hold can install on the wall parallelly. By installing the hold parallelly to the wall, the children can not only use it as a hold but also use it as a target because of the area of the hold is bigger than the normal hold.
By looking at the position of the hold, the route on the wall can be showed to children. And by locating the keypoint of the route, the route designer can design the route for children with cerebral palsy.

The other hold installation is perpendicular on the wall. As we mention before, when children arrive at the middle of the wall, they are tired and disappointed. Giving them a plate to let them stand stably could be a solution.
As it is showing in the figure below, the perpendicular position can also be used as a hold for the hand, but what is more, the hold can offer children a 250mm* 170mm area to stand, it is quite a big space to let the children stand even with two feet on it.
Therefore, in this two ways, the therapist can easily organize a adaptive climbing wall, since only few of the useless hold, in children's perspective, will be changing to the new hold. And the therapist can decide where to put the hold to help the children challange, rest, think on the wall.

Except using the product as a hold in the gym, the connect mechanisim also allow the therapist to connect other activity accessories on the hold in order to giving children more exercises on the wall. Previously, we find in the user journey map, children need some rewards to encourage them to repeat climbing exercises without feeling bored. By designing different accessories can offer different activities on the wall, put an end to produce bored.

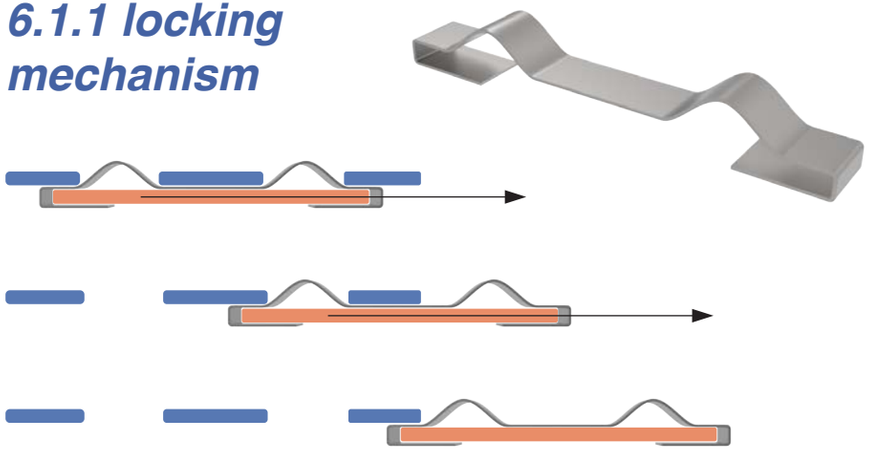
In the figure, I give you an example of game, named ball picking. In the game, the children can regard the ball as a award, and picking ball itself can really help children with fine manipulation exercises. The ball is a small component with theme, here is super hero, and texture, the thematic ball can attrat the children a lot, and the texture help them get to have tactile registerition therapy.



6. Final design

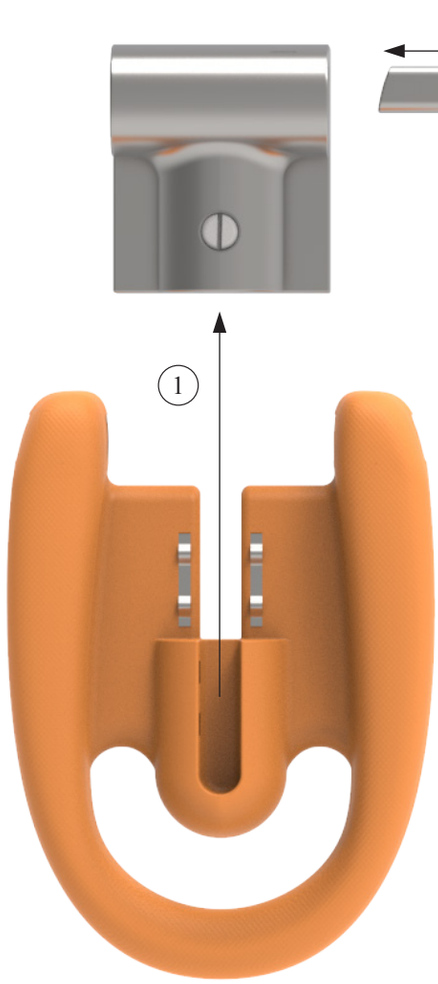
6.1 Climbing hold

6.1.1 locking mechanism



Quick release mechanism

In this thesis, there are some occasions that need to assemble and disassemble the two holds and the hold with the activity accessories, so that the quick release system should be used
After researching about the release system in the market and the force we need to maintain, the spring steel wire clips has been selected from the supplier Order trailer parts.com, and it costs 0.16 euros/piece.
By using this mechanism, we can fast release the different part in different pieces, and the spring can also give the soud feedback to let the user understand the system is locking well.

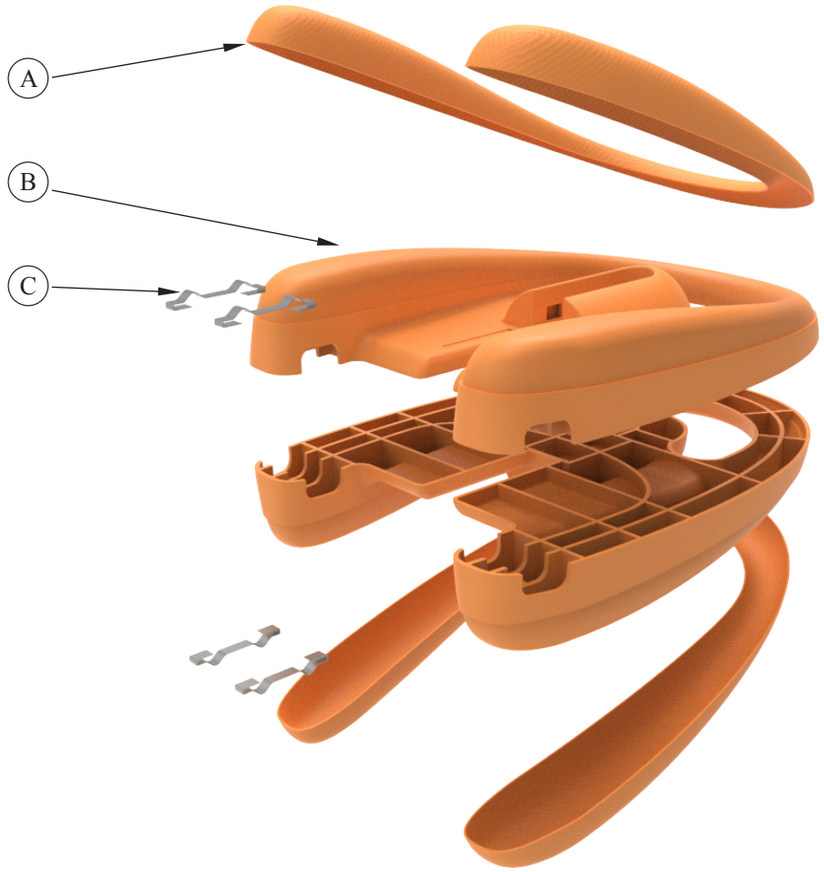


Rigid mechanical connection

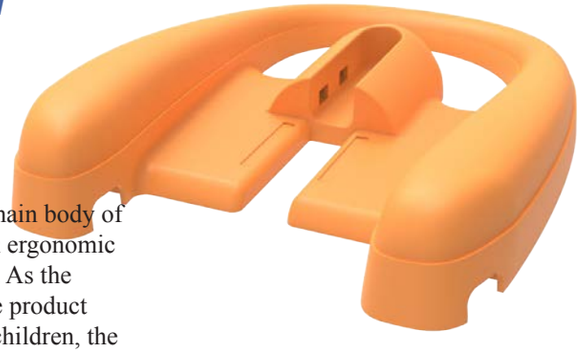
When the hold need to install on the wall, in order to get a completely safe structure, the quick disassembly structure will no longer be applicable at this time, we need a rigid mechanical connection structure.
Therefore, the rigid metal bar has been used to offer safty enough mechanical properties. And the metal bar has been designed with square section to avoid torque. Also the spring will also have their functions, which is to help the user install the hold with the metal link part with a proper position, and also give the sound feedback.

6.1.2 BoM

	PART	DESCRIPTION	MAKE OR BUY
A	Textured cover	Soft with texture	Make
B	Hold body half	Half hold	Make
C	Spring wire clips	Spring clip 5MM	Buy



6.1.3 Material selection



Hold body half

Concerning the shape, the main body of the hold is designed with an ergonomic and aesthetic angle in mind. As the thesis mentioned before, the product should be designed for the children, the part is shaped with smooth curves and not polygonal lines. It also shaped in such a way that the part need to have a grip shape part, and the grip part should integrate with the whole product in a unobstrusive way.
Associated with these form and functuinal characteristics there are some key properties that can be mentioned:
Mechanical Properties:

- High Young's Modulus (should be stiff such that it does not deform due to any external pressure or collisions)
- Good enough fracture toughness such that it doesn't crack on collisions or on moving in general.
- Density: Low enough mass to enable portability.

Thermal Properties: There are no specific need for the themal properties since there are no case for the hold to get near to the heat area, except throw it into the fire.
Optical Properties: Should not be transparent/translucent. The part shold be striking on the wall.

Acoustic properties: Should have a low acoustic velocity to not allow the vibrations/sounds produced by the friction between the hand and the hold to annoying children.
Magnetic Properties: Should be non-magnetic in nature as the hold may combine with sensor in the future, and being magnetic may affect the operation of the sensors.
Chemical Properties: Should be resistant to corrosion from magnesium powder and the disinfection water.
Price: Should be as cheap as possible.

Therefore, for the material in the application of being used as an climbing hold, following requirements are useful.
FUNCTIONAL:

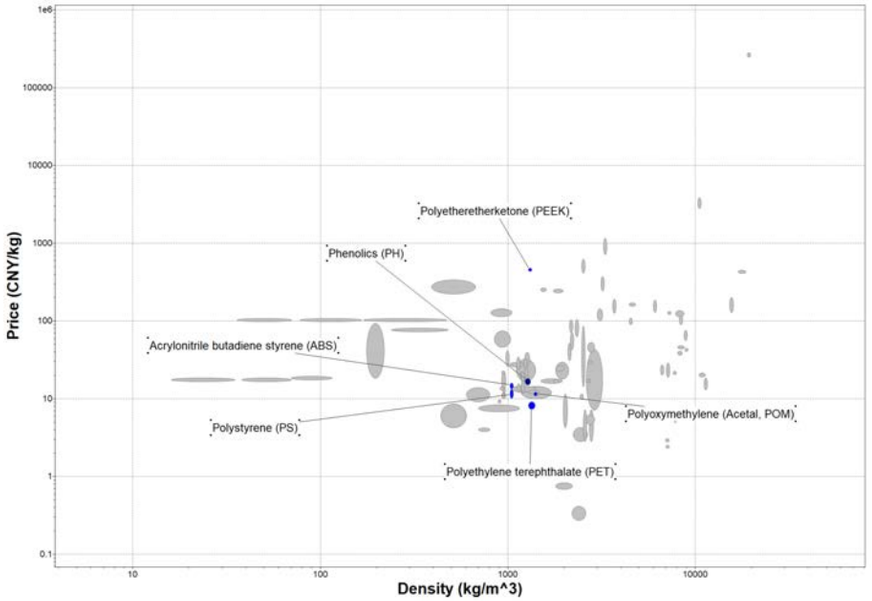
- Mass: Due to the dimensions of the component (curve of radius ~170 mm and height 250mm), the density of the housing material should be around 1000 kg/m3.
- Thermal conductivity should be in the range of 0.113-0.435 W/m℃
- Should minimize the passage of sound Excellent resistance to corrosion due to magnesium powder and the disinfection water.

AESTHETICAL:

- Color: Should be available in softer colour tones including grey and off-white.
- Finish: Should have a rough finishing/ ability to be finished with a rough coating.
- Transparency: Should be opaque

STRUCTURAL:

- Curve: Should easily flow and be molded to a curved shape.
- Stiffness: Should have a Young's Modulus in the range 2E+08 Pa to 4.82E+09 Pa, s.tthe component does not deform due to collisions etc.



Starting with the level 2 in CES material selection software, by insert all the limit in the software. The candidates are obtained in a graph between price and density. ABS seems like the most suitale choice. Since it has an important mechanical property of being impactresistant and tough, with a high fracture toughness and low density and price.

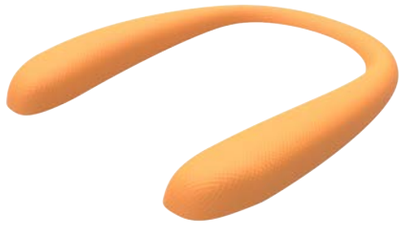
Textured cover

In the same process we can find the material we need for the small piece with texture.
The cover is also a part of the hold, which offer the different texture and a soft feeling. So it is almost the same shape of hold, but with softer and more elastic feeling.
Associated with these form and functional characteristice there are some properties that should be mentioned:
Mechanical Properties:

- Proper Young's Modulus (should not be so stiff and soft, should be soft enough to allow small deform, but the deform can not be too much.)
- Good enough tensile strengh, since the cover doesn't have too much stiffness, so it need to have a good tensile strengh to have a good elastic proformance.
- Density: low enough mass to enable protability.

Thermal Properties: There are no specific need for the themal properties since there are no case for the hold to get near to the heat area.
Optical Properties: Should not be transparent/translucent. The part shold be striking on the wall.
Therefore, for the material in the application of being used as an textured pat for climbing hold, following requirements are useful.
FUNCTIONAL:

- Mass: Due to the dimensions of the component (curve of radius ~170 mm and height 250mm), the density of the housing material should be around 1000 kg/m3.



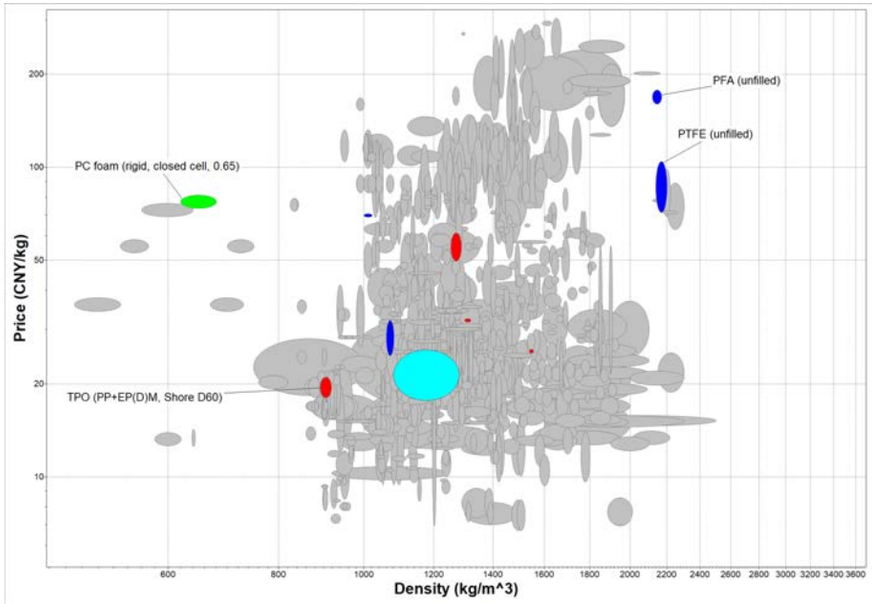
- Should be excellent resistance to corrosion due to magnesium powder and the disinfection water.
- Limited water absorbtion

AESTHETICAL:

- Color: Should be available in softer colour tones including grey and off-white.
- Finish: Should have a rough finishing/ ability to be finished with a rough coating.
- Transparency: Should be opaque

STRUCTURAL:

- Curve: Should easily flow and be molded to a curved shape.
- Stiffness: Should have a Young's Modulus in the range 3E+08 Pa to 1E+09 Pa.

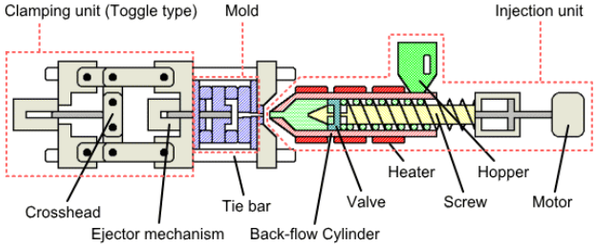


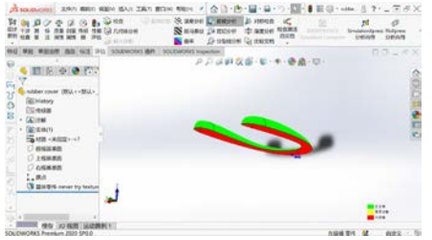
Starting with the level 2 in CES material selection software, by insert all the limit in the software. The candidates are obtained in a graph between price and density. ABS seems like the most suitale choice. Since it has an important mechanical property of being high elasticity and high strengh, and this material is widely used in toy production.

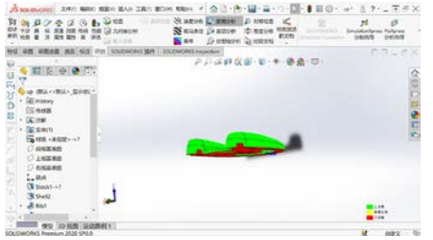
6.1.4 Manufacturing and jointing

Manufacturing processs

By checking the Processes that the CES software offer to the material we use, which was ABS and TPO. The inject moulding is the common one. Injection moulding is a manufacturing process for producing parts by injecting molten material into a mould. Injection moulding can be performed with a host of materials mainly including metals (for which the process is called die-casting), glasses, elastomers, confections, and most commonly thermoplastic and thermosetting polymers. Material for the part is fed into a heated barrel, mixed (using a helical shaped screw), and injected into a mould cavity, where it cools and hardens to the configuration of the cavity. After a product is designed, usually by an industrial designer or an engineer, moulds are made by a mould-maker (or toolmaker) from metal, usually either steel or aluminium, and precision-machined to form the features of the desired part. Injection moulding is widely used for manufacturing a variety of parts, from the smallest components to entire body panels of cars. Advances in 3D printing technology, using photopolymers that do not melt during the injection moulding of some lower temperature thermoplastics, can be used for some simple injection moulds.



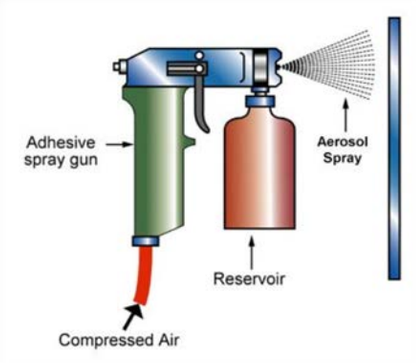




So the two part need to be designed with a one-degree of draft angle.

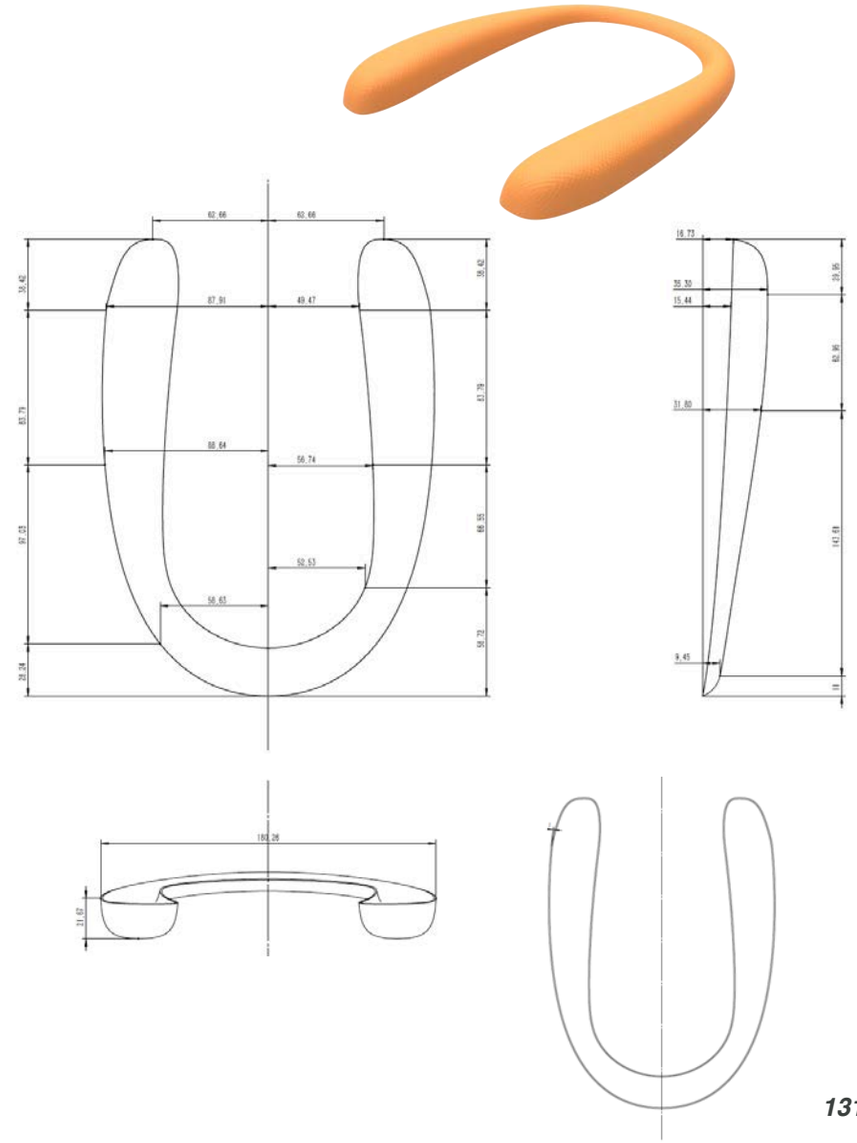
Jointing process

Since the two part didn't need to disassemble during the product life cycle, on the contrary, if the TPO layer falls off early, it will be a problem for users. So the adhensive could be a simple solution.
Here, base ont he information we get from CES software, Structural adhensives are selected.
Structureal adhensives are those that are used to perform some mechanical function, though they may have a secondary role as a sealant. Many are rigid, giving a stiff bond, but flexible adhesives also play an impotant role in design.

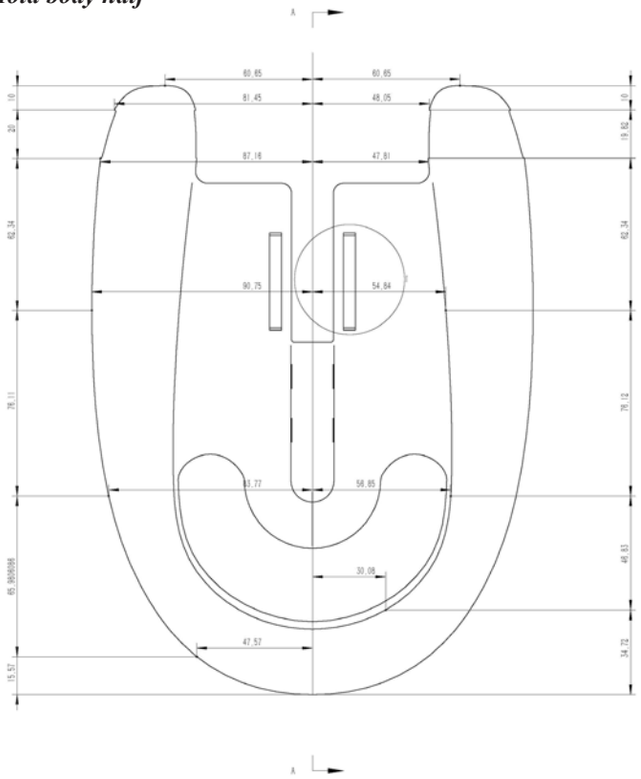


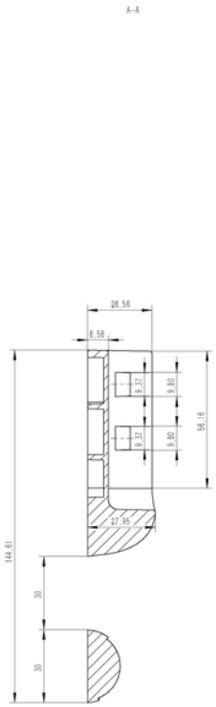
6.1.5 Technical drawing

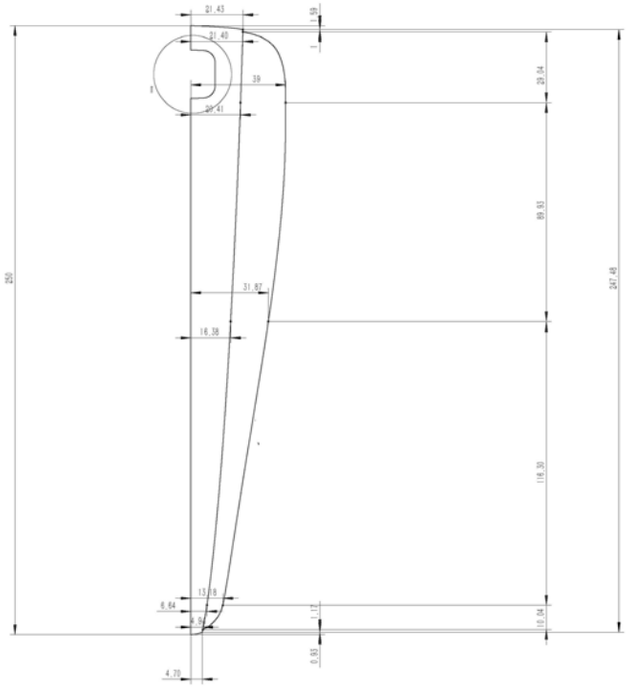
Textured cover

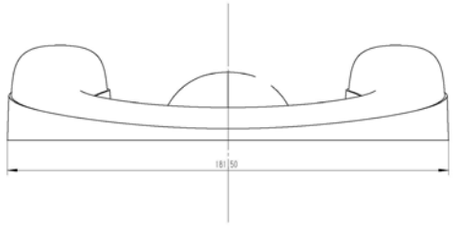


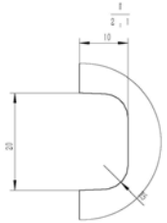
Hold body half

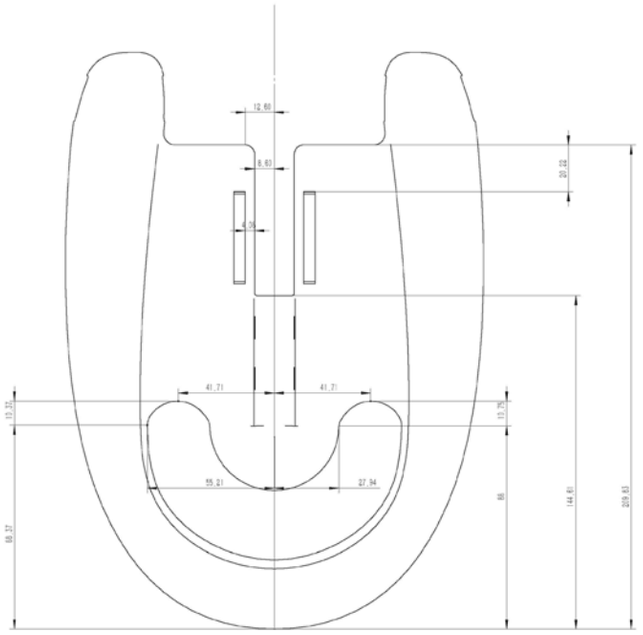


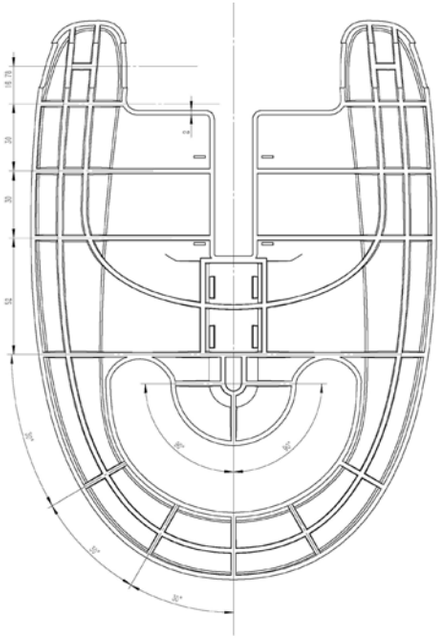












6.2 Cost analysis

Using the Ashby cost model to calculate the produce price of the whole product.

Hold body half

The price of raw material of ABS is found in Alibaba.com, with 2.9 euros/ kg. By insert the density 1.05*e3 kg/m3 into the solidworks software, we can get the mass of the piece is 0.21kg.

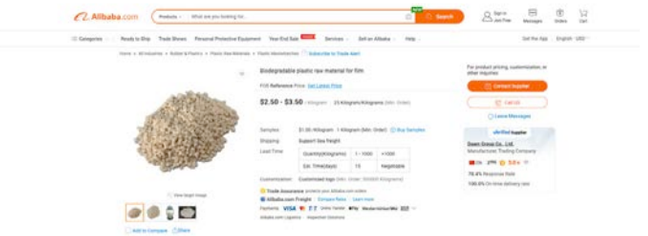
$C_1 = mC_m/(1 - f)$

m = 0.21 [kg/ Piece]

C_m = 2.9 [€/ kg]

f = 0,02

C1 = 0.62 [€/ piece]



DESCRIPTION	Category	Val.	Min	Max	Notes
Extruded rubber profile	Gasket	€	400	1000	Compartment with cost
Moulds for die cast aluminum	Inj.Alu.	€	10000	15500	Acc.Size
Moulds for die cast aluminum with opening mechanisms for extraction	Inj.Alu.	€	13000	22000	Acc.Size
njection moulds for plastic materials only cavities , standard or common older)	Plast.Inj.	€	3000	6000	Small sizes
Injection moulds for plastic materials (complete)	Plast.Inj.	€	8000	18000	Small to medium
Injection moulds for plastic materials (complete)	Plast.Inj.	€	27000	42000	Big sizes or optical finishes and materials
Polyurethane injection moulding	Poliurethane	€	52000		(Ex. Illiria)
Cutting and punching tools	Punch.Tools	€	2300	7000	Small sizes

By checking the leason of economic and corporate, the reference has been given during the leason, the tooling cost can be find there, this thesis take the maximum value since the size is small but the shape is complex, so the tooling cost is 6000€. With tool life nt=1000000/piece.

$C_2=C_t*[int((n/n_t) + 0.51)]/n$

Ct	n	nt	n/nt	int(n/nt+0.51)	C2
6000€	1	1000000	0.000001	1	6000
6000€	100	1000000	0.0001	1	60
6000€	10000	1000000	0.01	1	0.6
6000€	1000000	1000000	1	2	0.012
6000€	100000000	1000000	100	101	0.006
6000€	1000000000	1000000	1000	1001	0.006

S_t=Surface of the Mold

S_t=NominalAreaPieceProjected+ChannelsAndCavities

S_t=0.00018[m^2]+0.00018[m^2]*30%

S_t=0.00024[m^2]

PercorsoDelFlusso=(SideOfThePiece*√2)/2

PercorsoDelFlusso=(0.25[m]*√2)/2

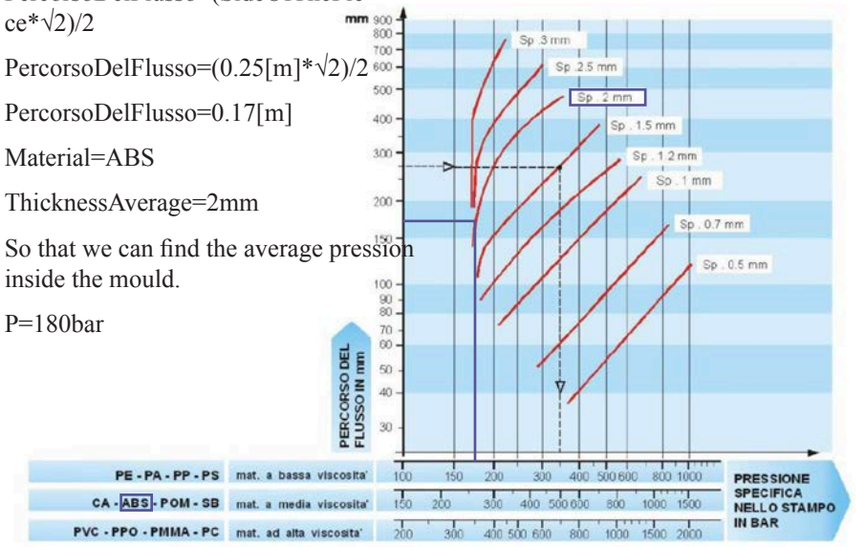
PercorsoDelFlusso=0.17[m]

Material=ABS

ThicknessAverage=2mm

So that we can find the average pression inside the mould.

P=180bar



F=Tons of a Mould [Force]

k=SafetyFactor(1.1)

P=averagePressionInsideTheMould

P=180[bar]

F=k*St*P

F=1.1*0.14256[m^2]*3.4*10^7 [N/m^2]

F=47520 [N]

F=4.9 [ton]

MACHINERY	80 TONS	135 TONS	270 TONS	300 TONS	500 TONS	700 TONS	1000 TONS	Number of moulding cycles per hour	Notes
Direct Cost Reference	€/h	€/h	€/h	€/h	€/h	€/h	€/h		
Machinery for injection moulding (aluminium)				60	70	80	100	around 100 to 60 decreasing with sizes and weight	
Machinery for injection moulding (plastic materials)	20	25	25	25	40	65	100	around 100 to 60 decreasing according the materials	Automatic process (smaller parts – 3÷4g – could have 15÷25s moulding cycle)
Machinery for injection moulding (plastic materials) with manual operations (co-moulding of inserts)	55	60	60	60	75	100	135	60 or less due to manual operations	(just only for reference, small series without automatization of the process)

C_3=20(€/ h)/100(piece/h)=0.2€/piece

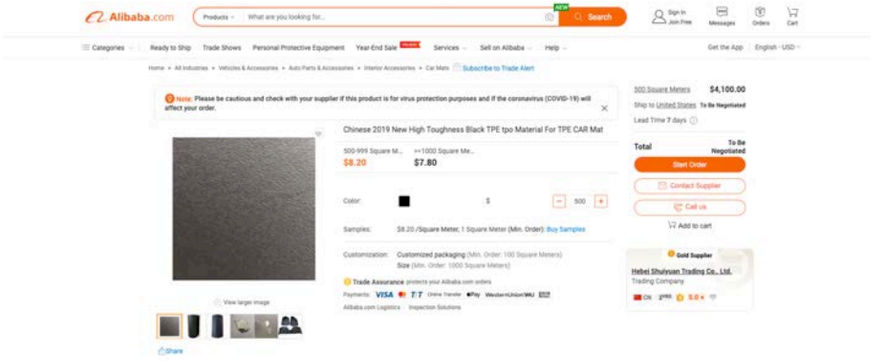
$C_4=C_{oh}/n$=58(€/h)/100(piece/h)
=0.58€/piece

$C_{tot}= C_1 + C_2 + C_3 + C_4$

If the batch is big enough the total cost to produce the single piece will be1.4€/ piece

Textured cover

Same process will use in this part since it uses the same manufacturing process.



$C_1 = mC_m/(1 - f)$

m = 0.023 [kg/ Piece]

C_m = 6.5 [€/ kg]

f = 0,02

C1 = 0.15 [€/ piece]

DESCRIPTION	Category	Val.	Min	Max	Notes
Extruded rubber profile	Gasket	€	400	1000	Compartment with cost
Moulds for die cast aluminum	Inj.Alu.	€	10000	15500	Acc.Size
Moulds for die cast aluminum with opening mechanisms for extraction	Inj.Alu.	€	13000	22000	Acc.Size
njection moulds for plastic materials only cavities , standard or common older)	Plast.Inj.	€	3000	6000	Small sizes
Injection moulds for plastic materials (complete)	Plast.Inj.	€	8000	18000	Small to medium
Injection moulds for plastic materials (complete)	Plast.Inj.	€	27000	42000	Big sizes or optical finishes and materials
Polyurethane injection moulding	Poliurethane	€	52000		(Ex. Illiria)
Cutting and punching tools	Punch.Tools	€	2300	7000	Small sizes

By checking the leason of economic and corporate, the reference has been given during the leason, the tooling cost can be find there, this thesis take the maximum value since the size is small and the shape is also simple, so the tooling cost is 3000€. With tool life nt=1000000/piece.

$C_2=C_t*[int((n/n_t) + 0.51)]/n$

Ct	n	nt	n/nt	int(n/ nt+0.51)	C2
3000€	1	1000000	0.000001	1	3000
3000€	100	1000000	0.0001	1	30
3000€	10000	1000000	0.01	1	0.3
3000€	1000000	1000000	1	2	0.006
3000€	100000000	1000000	100	101	0.003
3000€	1000000000	1000000	1000	1001	0.003

Since, this part is smaller than the previous one, so the tons of the mould will also less than 80 tons

MACHINERY	80 TONS	135 TONS	270 TONS	300 TONS	500 TONS	700 TONS	1000 TONS	Number of moulding cycles per hour	Notes
Direct Cost Reference	€/h	€/h	€/h	€/h	€/h	€/h	€/h		
Machinery for injection moulding (aluminium)				60	70	80	100	around 100 to 60 decreasing with sizes and weight	
Machinery for injection moulding (plastic materials)	20	25	25	25	40	65	100	around 100 to 60 decreasing according the materials	Automatic process (smaller parts – 3÷4g – could have 15÷25s moulding cycle)
Machinery for injection moulding (plastic materials) with manual operations (co-moulding of inserts)	55	60	60	60	75	100	135	60 or less due to manual operations	(just only for reference, small series without automatization of the process)

$C_3=20(€/ h)/100(piece/h)=0.2€/piece$

$C_4=C_{oh}/n=58(€/h)/100(piece/h)$
$=0.58€/piece$

$C_{tot}= C_1 + C_2 + C_3 + C_4$

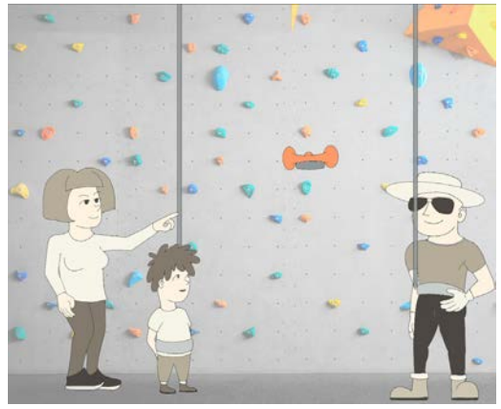
If the batch is big enough the total cost to produce the single piece will be 0.93€/ piece

By calculating all the cost together, the Prime cost will be 5.3€

6.3 Story board

At first, the therapist take the product and give some of them to the route setter in the gym. And tell them where should the hold need to be put on the wall. The coach in the gym is happy because he doesn't need to change a lot og holds on the wall.

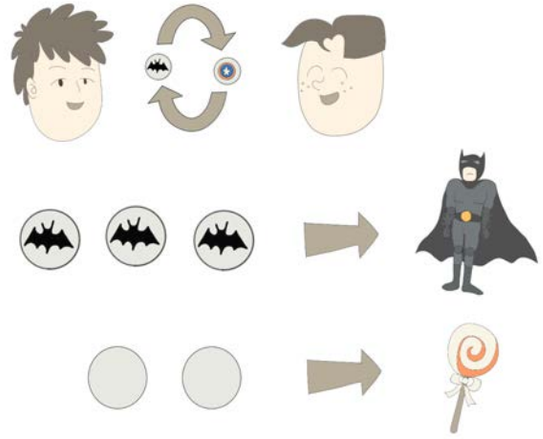
While the coach installing the holds on the wall, the therapist will introduce the toy mode to the children and let them start to play with it, in order to build the emotional connection between children and the wall through the hold. And the children is happy to have the toys



When child starts to climb, he will recognize the hold on the wall and the therapist can point out the first hold as a target to him, and encourage him to get their. The kid will release a little because there are something familiar to them.

When the child stand on the hold they will feel stable, since the hold offers him a stable and large enough place to stand. After few seconds the therapist will encourage him to get to the next target.

While he get to the top of the wall they others activities will provide them the extra happiness, here is the picking small ball activity, the ball can be regard as a award or they can collect the balls to change for another bigger award. At the same time, the themetic graphics also allow children to exchange between each other.



When they get back home, child can also play with the toy, to practise the motor movement of the hand. Also the activities at home can also remind him the memories while he is climbing, in order to enhance the affection of the climbing therapy.

6.4 Future development

This design is base on the research we get from the users, but here still the first version of the product, and because of the personal abilities and time, there still some missing part in the final design. Therefore in the future major developments can be made in order to improve the features of the product.

6.4.1 The hold

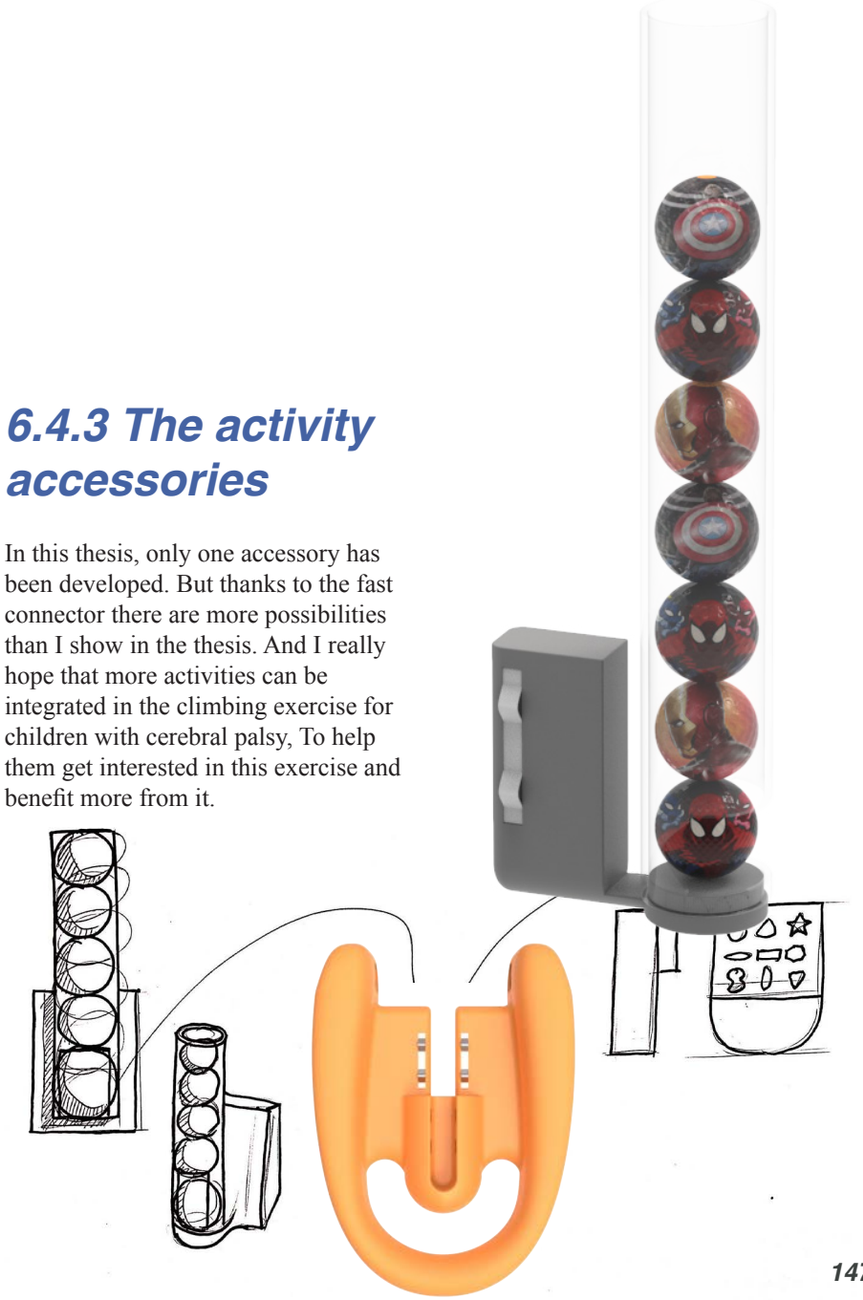
The hold is almost fully development, but there are still some aspect that need to improve. In further development, with the increasing of the batch size, the two hold with different color can be designed with different texture, or other color can be use to create a series of product.

6.4.2 The link

The link is the metal part which connect the hold and the wall.
Except investgating some detail design about this part, the shape can also be changed, the idea has been missed in this thesis, is adapting the shape to the normal climbing hold and have the basic hold function. The link can remain on the wall and be used as normal hold, when the professional climbers are using the wall. In this way, The gym can change the walls function, from adaptive wall to the professional climbing walls, quicker.

6.4.3 The activity accessories

In this thesis, only one accessory has been developed. But thanks to the fast connector there are more possibilities than I show in the thesis. And I really hope that more activities can be integrated in the climbing exercise for children with cerebral palsy, To help them get interested in this exercise and benefit more from it.



6.5 Conclusions

The product developed in the thesis can bring an improvement to today's climbing therapy for children with cerebral palsy.
In fact, there is just few adaptive climbing products in the market, Not mention a profuct which can help them to remeber the experience of chlimbing

New hand position on the wall

There are barely grip hold in the normal indoor climbing wall, since the indoor climbing sport is a easy version of the outdoor climbing, and closing the hand to grab something is the easiest thing that the climber are not willing to practise. But closing hand is very difficult for children with cerebral palsy, so if they can practise this position on the wall or not means a lot to them.
In this way, the grip shape has been integrated in the total shape of the climbing hold, in order to further reduce the difficulties of climbing exercise and full the blank of hand position which the normal hold did not provide.

Integrated sensory therapy

Two part in the product can really help children with their tactile registerition therapy.
One is the small ball with themetic grapic. Different balls have different textures, when children get it from the climbing exercise and start to recogonize the texture by touching and playing it, afterward, when he gets back home he can play the ball our product also, different texture will cause different rolling speed, and they can feel the texture also in this dimension.
The other is the rubber cover on the hold, the rubber can, first of all, increase the friction between the children's hands and the holds, make children feel stable. Otherwise, the texture on the hold can build a relationship between children and the hold, when children start get familiar with the hold, when they arrvie to the gym, they can recognize the hold also by the texture.

Toy mode

The climbing activiy and domestic therapy are connected by the toy mode. The hold can be used both in the gym and at home, and different function has been offered.
When the holds are used at home, the toy function are used to attract children to interact with the hold. In this way, children can have practise conciously.

Create a small target on the wall

The hold is bigger than the normal holds, and the color is more vivid than the others. Therefore, the hold on the wall will attract children's attention more. In this way, the therapists can use the hold as a target in the middle of climbing scenario, to help the children rest and gain more confidence to reach the top of the wall.

Using different activities to attract chilren

The connect mechanism has been designed in a really economic way, the accessories can be designed to drive more activities which can play on the ground to the wall. With more activities, children will never geting bored on the wall, they can play all the time on the wall until they are getting tired.

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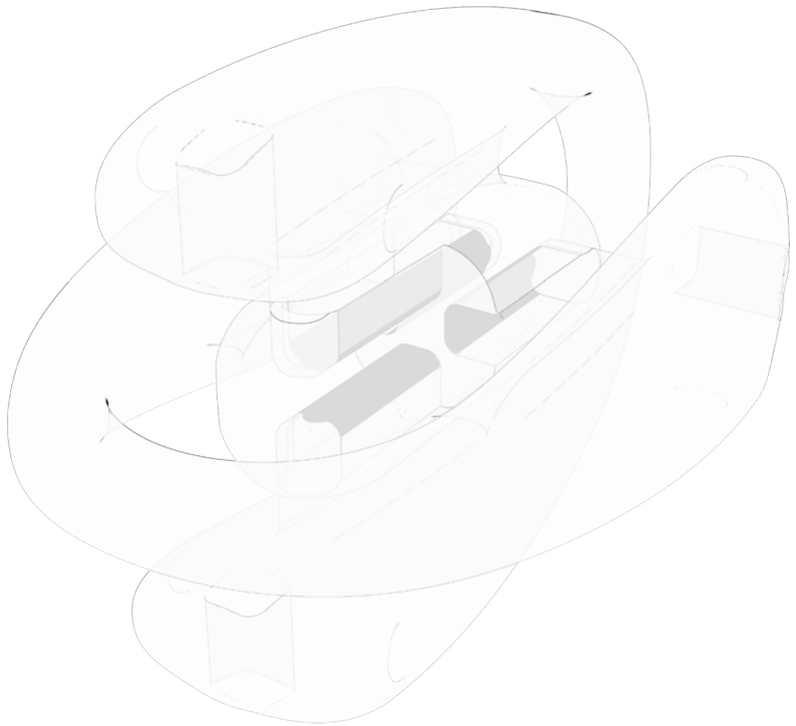
Acknowledgments



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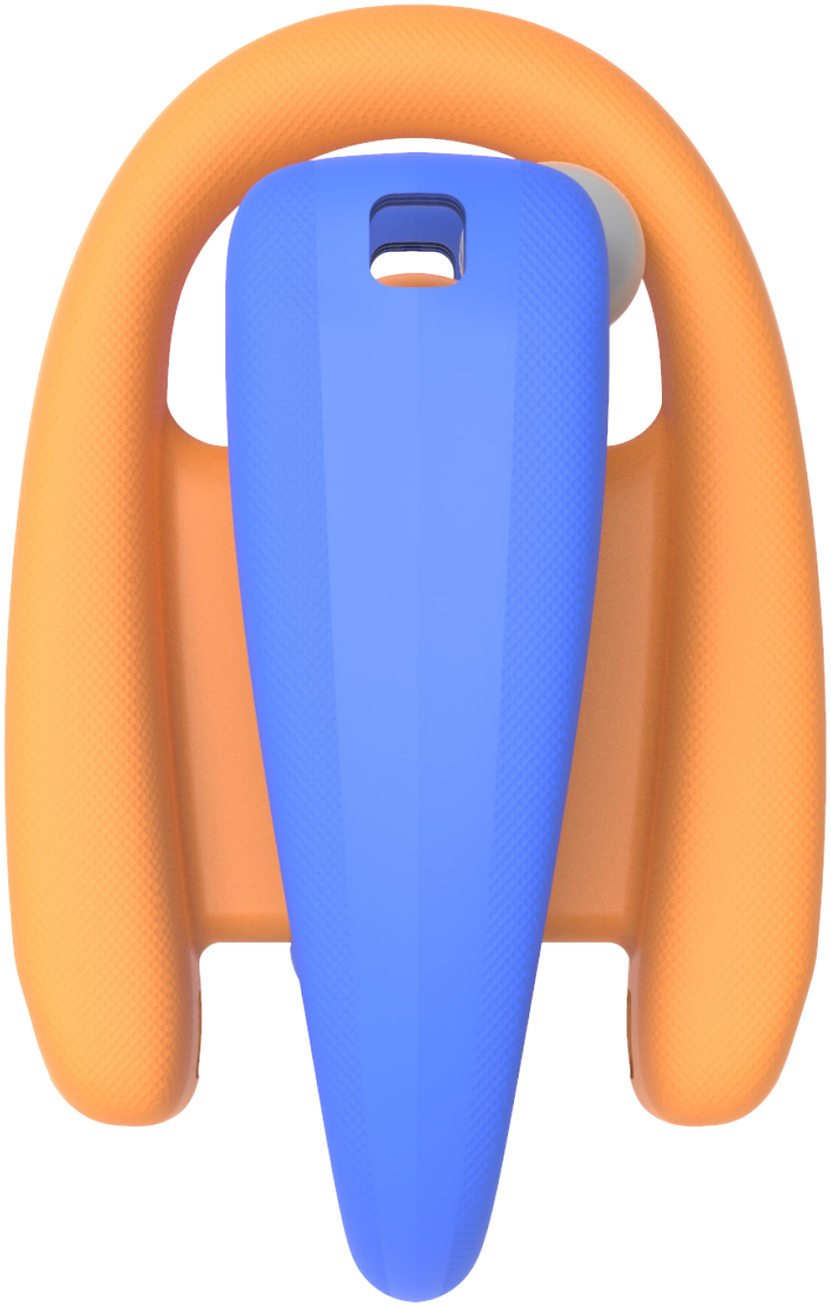

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