# 'Redesign of a Vestibulator for the children with Cerebral Palsy '

Submitted in partial fulfilment of the requirements
of the degree of
Master of Design

By

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INDIAN INSTITUTE OF TECHNOLOGY BOMBAY

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# Redesign of a Vestibulator for the children with Cerebral Palsy

Project 2

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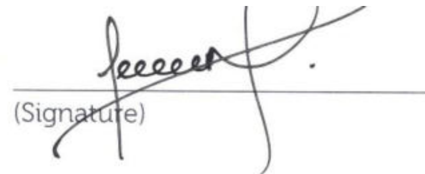
I declare that this written submission represents my ideas in my own words and where other ideas or words are included, I have adequately cited referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified ant idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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# Approval sheet

Industrial Design Project 2
**Redesign of a vestibulator for the children with cerebral palsy**

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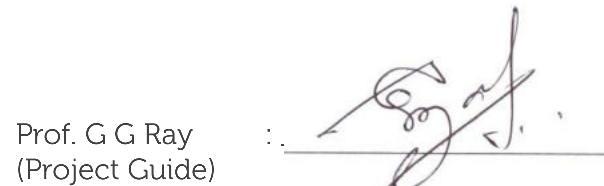
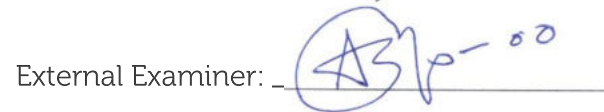
is approved as a partial fulfilment of requirement of post graduate degree in Industrial Design



Prof. G G Ray : ____________
(Project Guide)



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# Abstract

The aim of this project is to redesign a therapeutic equipment for treating children with Cerebral Palsy.

CP or Cerebral (brain) Palsy (malfunctioning) is a birth related disorder in children which damages specific parts of the brain which controls their posture, muscle movement and co-ordination. An organ called the vestibular organ behind our ear gives the sense of balance, posture and co-ordination in us. This organ malfunctions in the children with CP. So, these children may not be able to sit, stand or walk depending on the severity of their CP. Hence, we need to assist these children. They can be brought to a better life by treating them with therapeutic exercises that can externally stimulate the vestibular organ. This product stimulates the vestibular organ of the CP affected children in three different axes through linear, gravitational, rotational and tilting motions in different combinations of postures like sitting, standing, kneeling, prone, supine and quadruped.

The 'redesign' is developed by bench marking the vestibulator designed by Dr. Sayyed Ali Hosseini (as part of his P.hD programme at Industrial Design Centre, IIT Bombay, 2007). Also, the parallel products in the market were also studied. The redesign is suited for physiotherapeutic centre scenario for treating children with 2-6 years of age. Betterment of the CP children are the primary concern.

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# 1. Introduction to Cerebral Palsy

*Cerebral palsy caused by damage to one or more specific areas of the brain, usually occurring during foetal development, or during infancy hence it occurs before, during or shortly following birth †.*

Do you know that when a baby is born he/she start to cry? This is a indication that the baby breathes and consumes oxygen. So do the babies need oxygen when they are in the womb? Yes they need and it reaches their brain through the umbilical cord. So if the foetus don't get enough oxygen, it could result into the damage of the brain cells and could affect the foetal development.

So, if the brain cells are damaged, could result into Cerebral Palsy(CP) which is an umbrella term for a group of chronic conditions affecting posture, body movements and muscle co-ordination.

*CP is neither progressive nor communicable, it does not get worsen †*

The children having cerebral palsy will have it throughout his life. They will have inability to get full control of motor movements like muscle control. Co-ordination and balance. *The incidence of cerebral palsy in developing countries is more than 3 cases per 1000live births. 25 lakh people of Indian population suffer from cerebral palsy and 150 children with the same are born everyday.†* So is there any way to reduce the problem faced by them? How can we help them to lead a productive life? Answers to these questions gives the direction for the design of a good therapeutic program and this is necessary for improving the children with Cerebral Palsy.

*†Vestibular stimulation on Cerebral Palsy (Hosseini, 2007)*

# 2. Therapy for Cerebral Palsy

*When infant or child has brain damage, a variety of symptoms can lead to suspect that something is wrong. In the first few months of life, an infant with brain damage may demonstrate some or all of the following symptoms:*
- *Abnormal posture*
- *Motor delay development*
- *Disequilibrium*
- *Abnormal reflexes*
- *Low, high, fluctuating muscle tone*
- *Seizures, eye fluttering, body twitching*
- *Trembling of the arms and legs †*

So when will we come to know that the baby has CP?
When the baby with brain damage reaches 6 months of age, the parent will be noticing that their child is slow in picking up movements than it is supposed to be. It is well seen in motor developmental activities like rolling over, sitting up, crawling and then finally to walking.

When a normal baby is born, he/she has no control over the muscle initially and the control over body movement, posture , co-ordination and balance is developed in time where as the CP baby, with the damaged brain cells cant reach like the normal ones. Lets quote this with an example. The healthy baby does not roll over in the first attempt. Or a baby while learning to walk, first he gets some support to stand properly, and slowly keeps one step, then falls down and tries again and again and then finally develop the motor skills. So they are getting a feedback themselves that with this particular amount of force from coordinated muscle contraction, I can roll over. With this particular force developed by muscles I can walk around. So they have a control over their muscles, posture and balance. This lacks in the CP affected kids and they cannot learn things themselves. This is because their brain cells cant stimulate themselves. So by therapeutic program we can stimulate the neurons and help hem to reach the motor development milestones but not like the normal babies. So in early ages of a CP baby, before 2yrs of age, if treated with a good continuous

*†Vestibular stimulation on Cerebral Palsy (Hosseini, 2007)*

therapeutic program, the baby could adapt to a better life. But CP will follow him for his life. There is no cure.

Children who receive good treatment not only have fewer movement limitations, but also have better postures, better muscle development, and better abilities in toileting, feeding, and dressing themselves. Furthermore, therapy programs enrich
children's lives by enabling them to explore and experience activities that they might not otherwise be able to do independently. The vestibular system is considered to play an integral role in the control of posture and balance.

*Cerebral Palsy is a persistent disorder of movement and posture appearing in early life and due to a developmental non-progressive disorder of the brain †*

*†Vestibular stimulation on Cerebral Palsy (Hosseini, 2007)*

# 3. Review of literature

## 3. 1 cerebral palsy

*Cerebral refers to brain and palsy refers to damage. It is not new and it has been there since the human evolution. It was first identified by a British surgeon named William John Little in the 1860s. CP is an umbrella term for a series of brain disorders and Dr. Little identified Little's Disease which later cam to be known as spastic diplegia.*

*Little believed that CP was caused due to the complications in birth and later, Dr. Sigmund Freud suggested that the cerebral palsy might be caused earlier in life, during the brain's development in the womb. And the study from more than 30 thousand CP births, scientists concluded that birth trauma was the reason for nearly 1000 births and they couldn't figure out the reason for the rest majority of births. So the exact reason for most of the cerebral palsy cases is unknown.†*

## 3. 2 cerebral palsy classification

*There are two types of classification for cerebral palsy children as follows:*

- *Topographical*
- *Neuro - motor*

*The former depending on the body parts affected and the latter depending on the part of the brain that is damaged.†*

†http://en.wikipedia.org/wiki/Cerebral_palsy as on 26.9.2013

*Topographical is classified to (fig 3.1)*

- ***Monoplegia**: any one body part (limb) involved*
- ***Hemiplegia**: One complete side involved either right or left.*
- ***Paraplegia**: Only both lower limbs involved.*
- ***Triplegia**: any three limbs involved (very rare).*
- ***Diplegia**: four limbs involved, lower limbs more than upper limbs.*
- ***Quadriplegia**: four limbs involved but upper limbs more than lower limbs †*

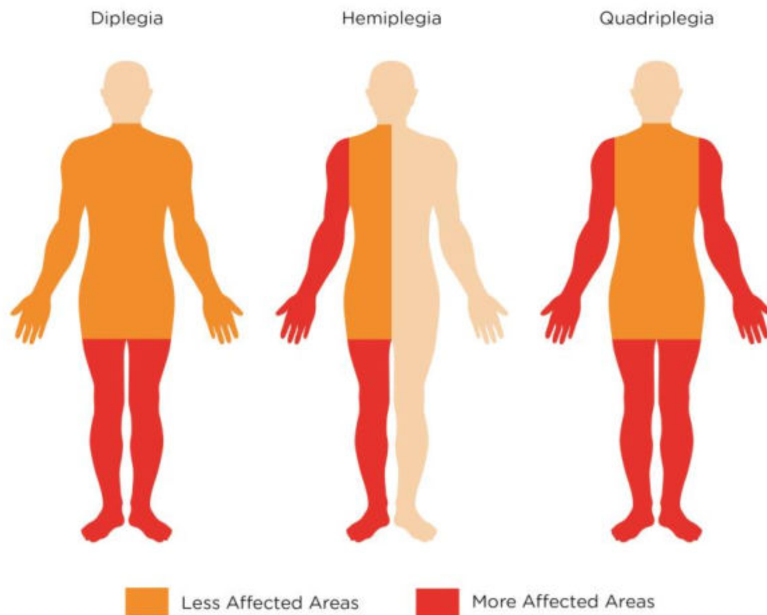



*Fig.3.1 Topographical classification of cerebral palsy*
*http://www.cpl.org.au/research/cp/types-of-cerebral-palsy as on 13.11.2013*

*Neuro-motor classification is as follows (fig 3.2)*

- ***Spastic:** the most common which comes around 70% of the total CP. Injuries to the pyramidal areas of the brain. The kids with spastic CP has stiff and jerky movements*

- ***Athetoid:** 10 % of total CP are found to be athetoid. Affects the extra pyramidal area of the central nervous system. It develops involuntary muscle movements in the child*

- ***Ataxic:** injuries to the cerebellum part of the brain. Low muscle tone and poor co-ordination of movements. They have problem with the sense of balance and the depth perception. They require a support always to stand and they always walk with their legs wide open.*

- ***Mixed:** comprises of another 10%. They have the tight muscle tone of spastic and involuntary movements of athetoid. Injuries to both pyramidal and extra pyramidal regions of the brain. Most common is the above stated but other combinations are also possible. †*

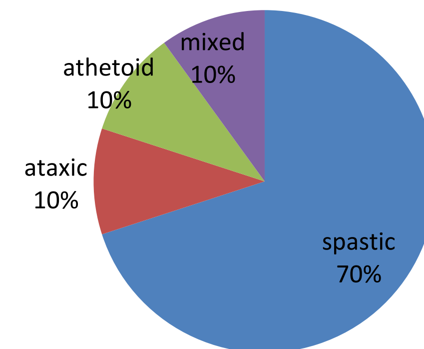



*Fig.3.2 neuro-motor classification of cerebral palsy*

*†Vestibular stimulation on Cerebral Palsy (Hosseini, 2007)*

## 3.3 vestibular function

Vestibular system in the body is one of the important sensory motor systems which involves in the maintenance of head and body equilibrium.

*Because the vestibular system is intimately connected with the auditory, visual, proprioceptive, and motor system, it works cooperatively with a number of other systems to modulate important functions, such as inhabitation of primitive reflexes and facilitation of postural patterns. The vestibular system has been credited with influencing muscle tone, spatial directionality, head and body orientation; and influencing learning and emotional development †*

### The role of vestibular function:

- Balance
- Sense of spacial orientation
- Stabilising the vision during body & head movement
- Perception of motion and position in absence of vision

## 3.4 vestibular system

*A pair of vestibular organs are located in our head behind the ears. To be precise, they vestibular end-organs reside the petrous portion of the temporal bone. Each temporal bone contains a tortuous cavity known as the bony labyrinth which is filled with **perilymph**. The bony labyrinth consists of three main parts: the **cochlea, the vestibule, and the semi-circular canals** (figure 3.3). Within each part of the bony labyrinth is **endolymph**, a fluid with high concentration of potassium. Cochlea converts acoustic energy into neural information. Vestibule is the **static labyrinth** because it induces tonic reflexes on postural muscles in response to changes in head and body positions and gravitational and inertial influences. The semi-circular ducts, contained in the semi- circular canals, convert inertial torques into information*

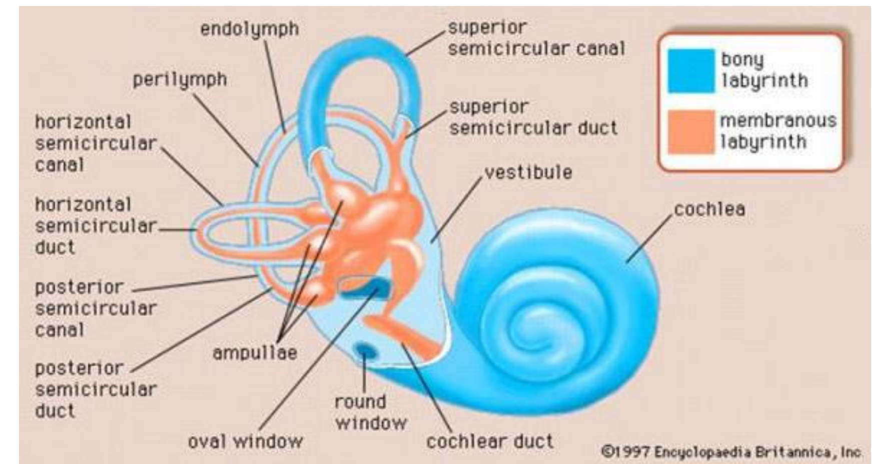



*Fig.3.3 the vestibular system in a human body*
*http://en.wikipedia.org/wiki/Vestibular_system as on 26.09.2013*

*about angular motion of the head hence this part is called the end organs of the kinetic or **dynamic labyrinth**, which signals head movement. When the head is moved, the endolymph is moved with an inertia where the perilymph moves with the head. †*

†Vestibular stimulation on Cerebral Palsy (Hosseini, 2007)

## 3.5 vestibular rehabilitation

*The idea is to stimulate the vestibular organ which will help on the partial recovery of the damaged nerve cells. Vestibular system is our internal reference telling the brain on how our head is orientated in space. The visual and somatosensory/ proprioceptive systems, on the other hand, are external references, providing our brain with information about the movement and stability of the world around us. Since the semi-circular canals are oriented in three mutually perpendicular directions, the therapeutic program should consist these modalities(fig 3.4):*

- *Gravitational ascending-descending movements*
- *Linear motion forward-backward*
- *Tilting motion forward-backward and side-to side*
- *Rotational movement , left and right spinning. †*

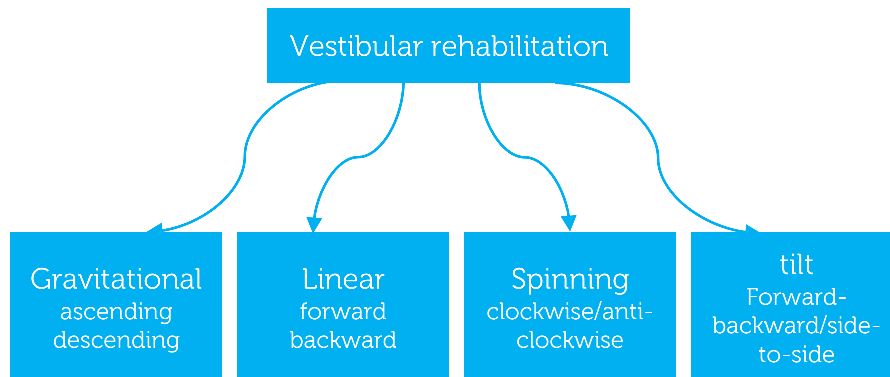



*Fig.3.4 the types of vestibular therapy*

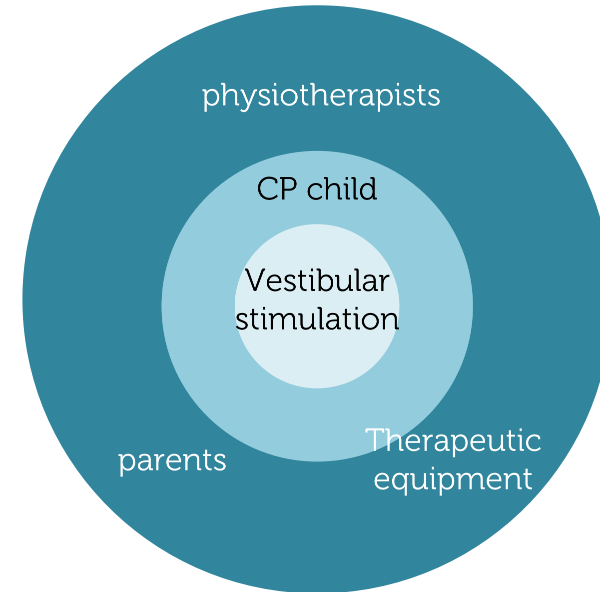



*Fig.3.5 vestibular stimulation environment*

As shown in Fig 3.5, the vestibular stimulation for CP child is achieved with the help of the physiotherapists, the therapeutic equipment and the parents.

*†Vestibular stimulation on Cerebral Palsy (Hosseini, 2007)*

# 4. Study of the existing product

vestibulator 1

*Fig.4.1 Vestibulator 1 for gravitational ascending-descending/linear/ spinning motion*

## 4. 1 product features

- Designed and fabricated in IDC Based upon the data on neuro-development evaluation and anthropometry collected from 67 children of which 41 from Children Orthopaedic Hospital, Haji Ali, Mumbai, Maharashtra, and 26 were from National Institute of Rehabilitation Training and Research (NIRTAR), Cuttack, Orissa.
- Stimulation of all receptors of vestibular system including forward-backward tilting, side to side tilting, spinning, forward-backward linear and gravitational ascending-descending motion.
- The vestibulator provides all different postures
- to be used for children from 2 to 6 years of age.

The design consists of mainly two parts
- **The positioning part**
- **The stimulator part**

Positioning part is where we position the child for the therapy and the stimulator part is the mechanism part for the various operations.

The positioning part was developed based on Anthropometric data on CP children from one to six years old and provides facilities for different position like prone, supine, sitting, quadruped, kneeling, and standing. Stimulator part provides different vestibular stimulation including tilting (forward-backward and side to side), spinning, forward-backward linear motion, and gravitational ascending-descending. All the positioning components are detachable, and adjustable to provide convenient different positions and support, so that all types of vestibular stimulation in different position can be performed for children with cerebral palsy from one to six years old.

There were two products developed
- **Vestibulator 1** for gravitational ascending-descending/linear/ spinning motion
- **Vestibulator 2** for forward-backward/side-to-side tilting motion

The child is positioned in the platform of the vestibulator for various combinations of position and movements and the therapeutic program is conducted. The child may be strapped or without strap considering the extend of CP that the child has. Initially the program starts with maximum support and in the future is reduced  when the child is familiar with the machine.

## vestibulator 2

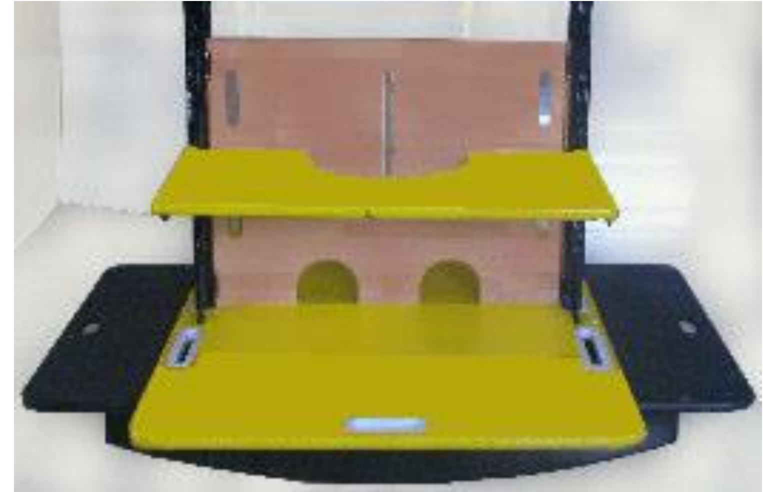


*Fig.4.2 Vestibulator for forward-backward/side-to-side tilting motion*

## 4.2 therapy positioning

*Fig.4.3 prone position for spinning/gravitational ascending-descending/linear motion*

*Fig.4.4 prone position for forward-backward tilting motion*

*Fig.4.5 supine position for forward-backward tilting motion*

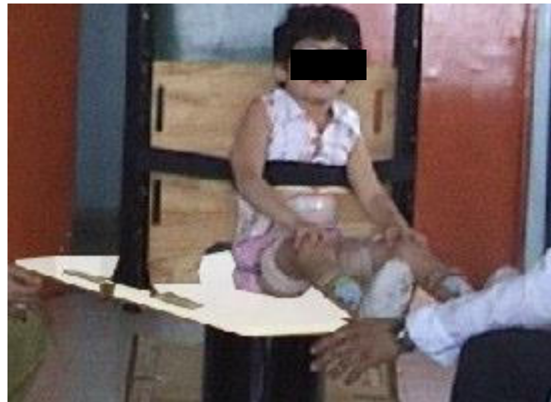


*Fig.4.6 sitting for spinning/gravitational ascending-descending/linear motion with maximum support*

*Fig.4.7 sitting for spinning/gravitational ascending-descending/linear motion with only back support*

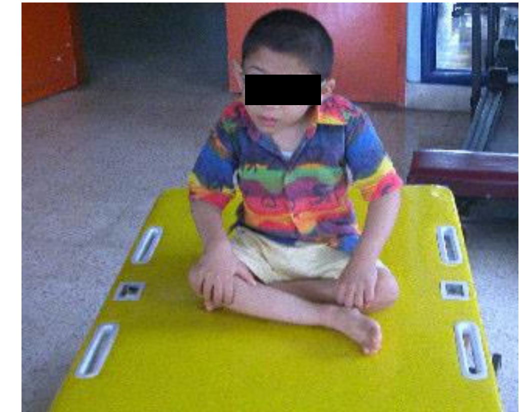


*Fig.4.8 sitting for spinning/gravitational ascending-descending/linear motion with no support*

*†all images above courtesy: Vestibular stimulation on Cerebral Palsy (Hosseini, 2007)*

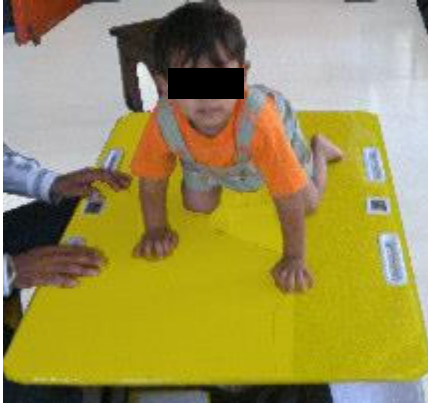


*Fig.4.9 therapy in quadruped position spinning*

*Fig.4.10 side-to-side tilting with tray*

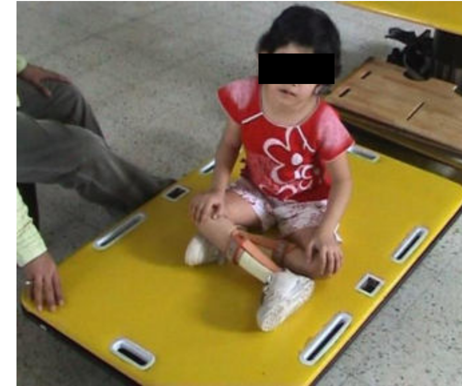


*Fig.4.11 sitting position for forward-backward tilting motion with no support*

*Fig.4.12 quadruped position for forward-backward tilting motion with no support*

*Fig.4.13 kneeling for spinning/gravitational ascending-descending/linear motion with maximum support*

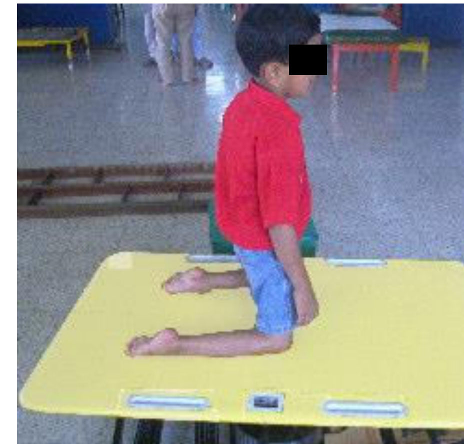


*Fig.4.14 kneeling for spinning/gravitational ascending-descending/linear motion with no support*

*†all images above courtesy: Vestibular stimulation on Cerebral Palsy (Hosseini, 2007)*

*Fig.4.15 prone standing board position for spinning*

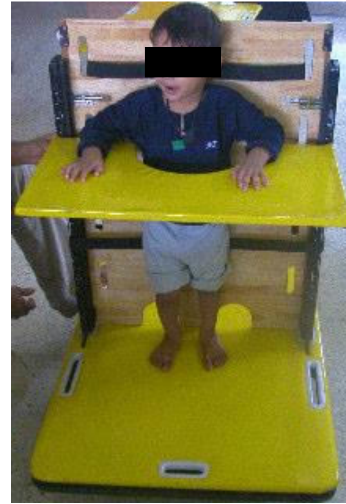


*Fig.4.16 supine standing board position for spinning*

*Fig.4.17 standing with no support*

*†all images above courtesy: Vestibular stimulation on Cerebral Palsy (Hosseini, 2007)*

# 5. User study

## 5. 1 visit to centre for child development, Haji Ali

As part of the user study, several visits were conducted to the Centre for Child Development, Haji Ali, Mumbai where the existing product is donated for the therapeutic program. Visited the therapeutic department and saw how the treatment is given to the children. I also had discussion with the physiotherapists in there. These were the comments about the existing product by the physiotherapists.

Dr. Purvi Ladhani
Senior Physiotherapist

*"We don't use the vestibulator much. It takes lot of space and It needs lot of effort to make it work and requires 2-3 persons at a time."*
*"it need to be taken out every time and put back into position"*
*"sometimes we ask the parents to use the therapeutic device and it is very difficult for them to manage"*
*"we have alternatives like the balance board, trampaulin and wobble board which are easier to use"*

Dr.Suraj Vaja
Physiotherapist

*"difficulty in neck holding. Its not easy to fix the ACO and Flat trays"*

*"we use it only for kids with bad trunk control (In supine standing board)"*

Dr.Michelle Barboza
Physiotherapist

*"its not easy to adjust the vertical plates and the straps can be misplaced"*

*"all the positions can be achieved in the device, but its about the difficulty in using the vestibulator"*

So because of these reasons , they were not keen in using the vestibulator and it was difficult to understand the problems since they are not using it much. A study was conducted to know how the therapy is done.

## 5. 2 observations

The physiotherapist lifts the child to the vestibulator and straps him to the vertical plates and starts to push the platform down. The spring in the stimulator cylinder compresses and gives a gravitational ascending descending motion.

**Key findings:**

*They use two children at a time for the therapy:*

Even though the design of the spring is to accommodate one kid at a time, the product visually does not appeal that it is for the treatment of one kid at a time. So when two kids are treated at a time, the entire spring goes wrong.

*The physiotherapist in wrong posture and doing in a wrong way:*

The product is designed to sit and operate, but the physiotherapist takes the standing posture to treat the children because he needs to care for the kid as well as to perform the therapy. This design is developed so as to have

*Fig.5.1 the physiotherapist in a bad posture, exerts force at the end of the platform which requires more force to compress the spring (designed to sit and excert force on the area near the cylinder*

the parents assistance while operating the vestibulator. This is fine when there is one child per the therapist. But when the number of patients increases, it becomes difficult for the therapist to manage all of them and he/she asks the parents to perform the therapy.

*Need of more people for operation:*

When the child is of 2yrs of age its easy for the therapist to lift them to the vestibulator, but difficult when they treat a child of 5yrs or above. So as it is shown in figure 5.1, the therapist performs in a wrong way which results in the improper stimulation of the vestibular system as well as health problems

*Fig.5.2 physiotherapist and the attendant in a bad posture, in synchronised speed. the strap sets are not supportive and reduced child-physiotherapist interaction*

*Fig.5.3 more people needed to perform the tasks*

to the therapist because of wrong posture. So he/she calls for assistance and they have to perform the therapy in synchronised motion. Here we can see that the child-physiotherapist interaction which is much needed for the success of the program is less and the child is frightened of being tied to the vestibulator. Its true that initially the child will be scared but the subsequent therapy will make him feel comfortable if there is a better therapist-child interaction. As shown in fig.5.3, the therapist needs lots of assistance when he needs to do the strapping. But strapping is not necessary in all the kids. Full strapping is done only for extreme cases of CP, which will prevent them from falling down and having injuries. But the physiotherapists are on the opinion that good strappings are needed for the treatment and they said that the kids will become scary in the initial stages and will later feel comfortable with it.

*They prefer alternatives:*

They prefer alternatives like the wobble board and the trampaulin which are easier to use. Those provide a better child-therapist interaction. But as shown in fig 5.4, they therapist carry a part of the kid's body weight and they are not feeling their weight themselves. This can be quoted with the help of another example. Lets consider a normal baby now. Some parents uses baby walker for their child and researches shows that this actually delays the walking of the child by a month. This is because they are not feeling their body weight and are not getting a feedback from walking and falling down. So this way of doing the therapy is not advisable.

*Fig.5.4 physiotherapist uses the alternatives like the trampaulin and the wobble board*

*Fig.5.5 & Fig 5.6 difficulty in operating the spinning vestibulator*

It can be seen from fig.5.5 and 5.6 that the operation of the spinning stimulator is neither easy in standing position nor in sitting. Manual hand operation for the spinning stimulator is a difficult task for the therapist. So there is good scope in the new design so as to make it easy for the therapist. Since the positioning platform is rectangular in dimension, it is not possible for the therapist to operate it in sitting position. So he has to bend down and rotate the platform.

# 6. Study of parallel products

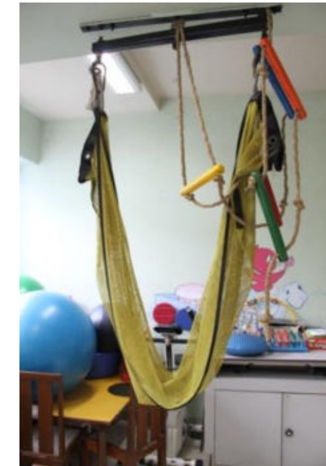


*Fig.6.1(a,b,c) different kinds of simple swing vestibulators*

Fig 6.1 shows the different types of simple swing vestibulators. The basic principle is the same for all these. They have a child positioning part. It could be the air filled circular tube(6.1a) or a foam filled inverted 'T' (6.1b) or a simple nylon swing(6.1c). They are hung from the ceiling and swung to and fro. The drawback is that they perform only forward-backward/side-to-side vestibular stimulation.

*Fig.6.2(left) a trampaulin for ascending-decsending*
*Fig 6.3 (top) a physioball*
*Fig 6.4 (right) a wobble board for forward-backward and side-to-side tilting vestibular stimulation*

Fig 6.2 shows a trampaulin on which the physiotherapist position the child for gravitational ascending descending motion. It is a spring loaded device. It does not work on the body weight of the child since the physiotherapist has to put efforts in lifting the child to give gravitational ascending descending vestibular stimulation.

Fig 6.3 is a physio ball. It is a gymastic ball which can be used to treat the CP kids. It is available in different sizes. It is constructed of elastomer and filled with air. The physiotherapist positions the child generally in supine and prone positions on the physio ball. The ball is rolled to and fro on the floor to give the vestibular stimulation to the child

Fig 6.4 is a wobble board which is similar to a seesaw. Again the child is positioned on the wobble board and the therapist tilts the board forward-backward or side-to-side.

Fig 6.5 is a barrel roll with thick foam support.. As shown in the figure, the child is positioned to get a forward-backward vestibular stimulation.

Fig 6.6 is a balance beam in which the child is positioned to walk over a 10-15 cm elevated beam.

Fig 6.7, Fig 6.8, Fig 6.9 shows the different vestibulators available in the market for swing vestibular therapy. The major drawback of these vestibulators is that these requires a huge space for installation.

## Conclusion

*The vestibualtors available in the market does not perform different combination of position and motions and thereby making the proposed vestibulator an unique design.*

*Clockwise from top*
*Fig.6.5 a barrel roll*
*http://www.bpp2.comas on 13.11.2013*

*Fig.6.6 balance beam*
*http://www.bpp2.comas on 13.11.2013*

*Fig.6.7, fig.6.8, fig.6.9 various swing vestibulators for forward-backward/side-to-side stimulation*
*http://www.rehabmart.com as on 13.11.2013*

# 7. Design brief

To redesign *the vestibulator for children with Cerebral Palsy†* which will find new dimensions in form, functionality, ergonomics, material and manufacturability of the product.

The vestibulator to be proposed will accommodate CP children with 2-6 yrs of age and is to be used in therapeutic centre scenario. Betterment of CP children are the primary concern.

*† It has been designed by Dr. Sayyed Ali Hosseini as part of partial fulfilment for the degree of Doctor in Philosophy (2007).*

# 8. Project overview

*Fig 8.1 project overview*

Safety for child

Proper strappings
Proper supports
Proper hip abduction
stability

Child-therapist interaction

Reduce the physical work by the therapist
Make therapist close to the child
Standing operation by therapist

Ease of operation

Proper mechanisms
Motorise the device
Provision for lifting the child to platform
Adjustable to all positions

Comfort for child

Form
material
Playful experience
Colour
Sound/music

size

Collapsible
Modular
Easy assembly-disassembly
Occupies less space

Improper methods of therapy

Lack of importance of vestibular therapy?
Visual appeal of the product
Easy adaptability to all exercises

Safety for therapist

Posture of therapist during therapy
No sharp parts
Should Lift the child to the vestibulator?

Fig 8.2 design directions

# 9. Concepts

### advantages

- combines vestibulator 1 with vestibulator 2
- Designed to stand and operate. Better interaction between the therapist and the child
- Easily adjustable for age 2-6
- Both hand and leg operated: ease in operation
- Can perform supine, prone, sitting, standing supine board, standing prone board, kneeling and quadruped positions in forward-backward linear, forward-backward/side-to-side tilt, gravitational ascending-descending and spinning motions.
- Can be easily disassembled
- Easy adaptation for different therapy positions
- Only one person required for the operation

### disadvantages

- Could frighten the child initially because of too much strappings.
- Need to lift the child
- Too much hand levers and adjustments
- No playfulness
- Leaf spring used may give a jerky movement

## 9. 1. concept 1

HANDLE
HAND LEVER
HEAD SUPPORT
TRUNK SUPPORT
SPINE
PELVIS SUPPORT
COLLAPSIBLE HANDLE
HIP ABDUCTION WEDGE
LEG RESTRAINTS
FOOT/ARM RESTRAINTS
HANDLE

*Fig.9.1 child positioning part of the concept 1*

SYNCHRONISED HAND AND LEG OPERATION FOR GRAVITATIONAL ASCENDING-DESCENDING

ROTATE THE PLATFORM FOR SPINNING LEFT/RIGHT MOTION

FOOT PEDAL

CALCULATED WEIGHT LEAF SPRING REDUCES THE BULKINESS OF VESTIBULATOR

*Fig 9.2 gravitational ascending-descending operation*

DETAIL A

LOOSEN THE SCREW FOR SWITCHING TO TILT MOTION

*Fig 9.`3 forward-backward/side-to-side tilt operation*

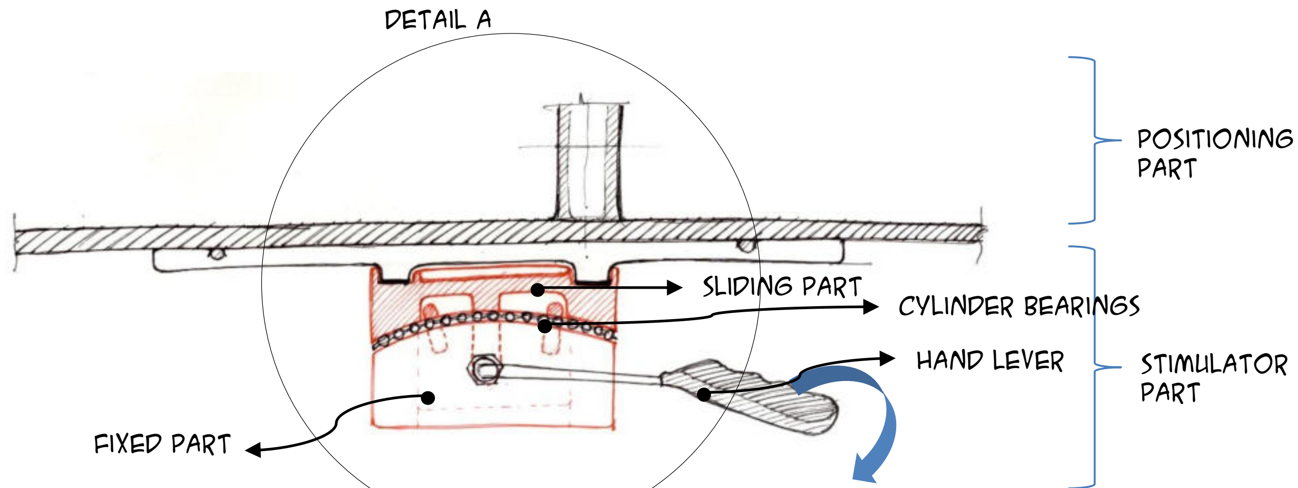



*Fig 9.4 mechanism that incorporates vestibulator 2 to vestibulator 1*

The mechanism that combines the vestibulator 1 with vestibulator 2 is as shown in fig 9.4. The lever when loosened, the sliding part can slide over the fixed part and thereby changing the vestibulator 1 to vestibulator 2. the sliding part slides over the cylinder bearings and thereby giving a smooth motion as well as resulting in the seas of operation

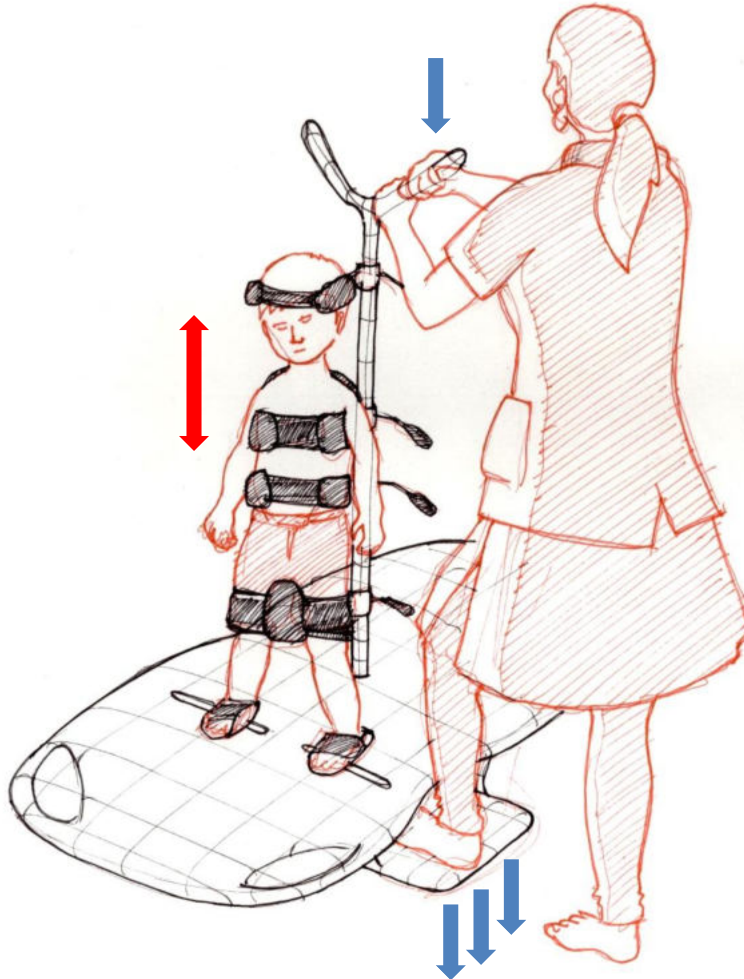


*Fig 9.5 vestibular stimulation in standing position*

## vestibular therapy in concept 1

Fig. 9.5 depicts the vestibular therapy in standing position. The physiotherapist lifts the child to the platform and straps him to the supports that slides in the spine of the vestibulator. There are four supports, i.e head support, trunk support, pelvis support and hip abduction wedge which will also support the legs in standing position. All the supports are not necessary for all the kids. So which all are not needed can be unscrewed an put to one side during the therapy.

Here the therapist gives gravitational ascending-descending motion manually. This way of doing the therapy was proposed because the physiotherapist is in a good posture in standing position, need to put less efforts compared to the 'sit to side and operate model and better child-therapist interaction which is much necessary.

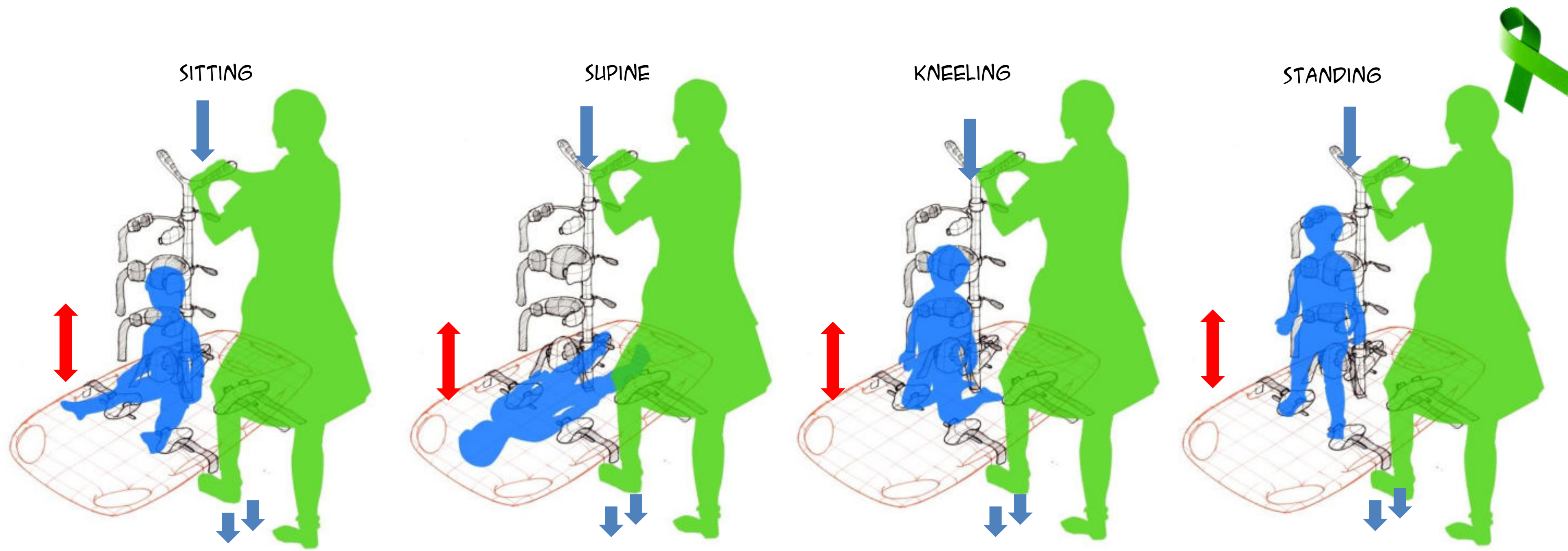



*Fig 9.6 the different positions of the child in gravitational ascending descending*

## advantages

- Compact and collapsable
- Adjustable/sliding strap set
- Easy storage
- combines vestibulator 1 with vestibulator 2
- Designed to stand and operate. Better interaction between the therapist and the child
- Easily adjustable for age 2-6
- Hand lever operated only
- Can perform supine, prone, sitting, standing supine board, standing prone board, kneeling and quadruped positions in forward-backward linear, forward-backward/side-to-side tilt, gravitational ascending-descending and spinning motions.
- Can be easily disassembled
- Easy adaptation for different therapy positions
- Only one person required for the operation

## disadvantages

- No playfulness
- Cannot perform spinning motion in supine and prone easily
- No hand rest provision for the child

# 9.2. concept 2

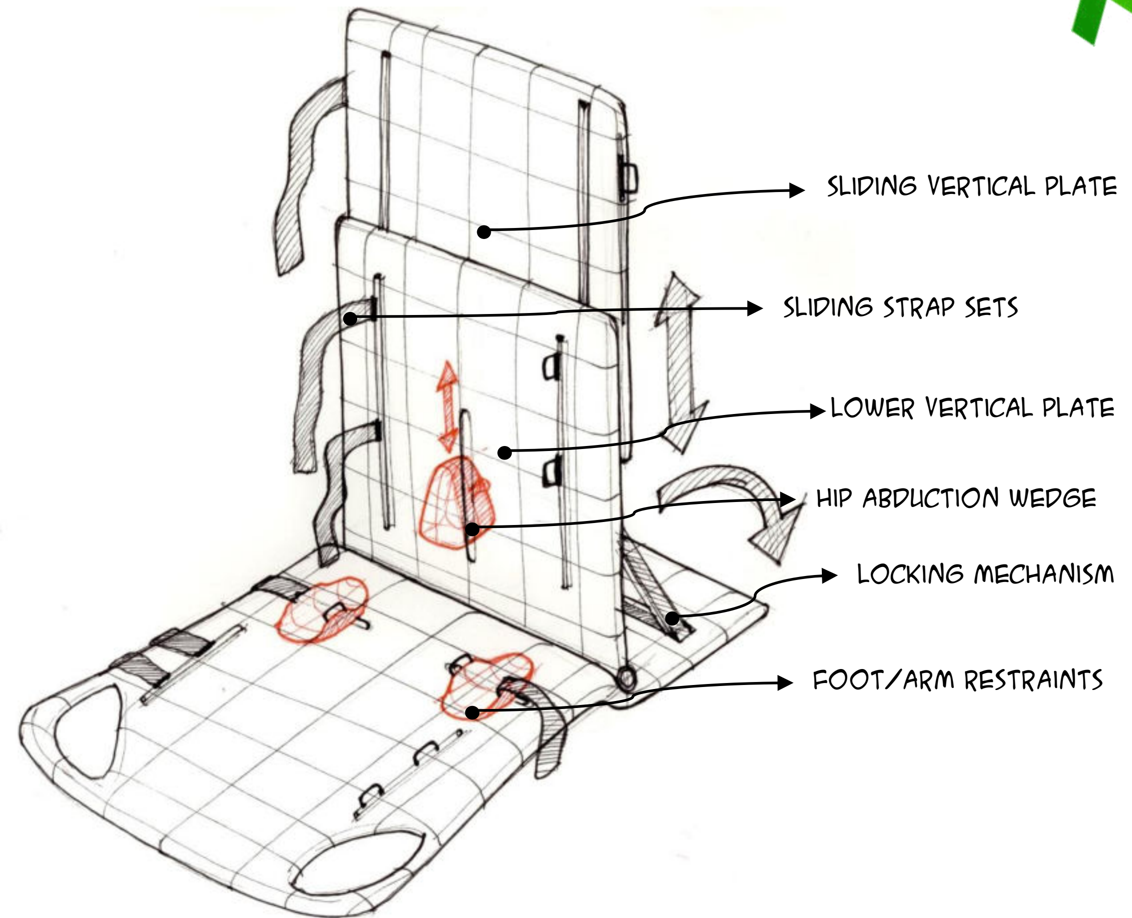



*Fig.9.7 child positioning part of the concept 2*

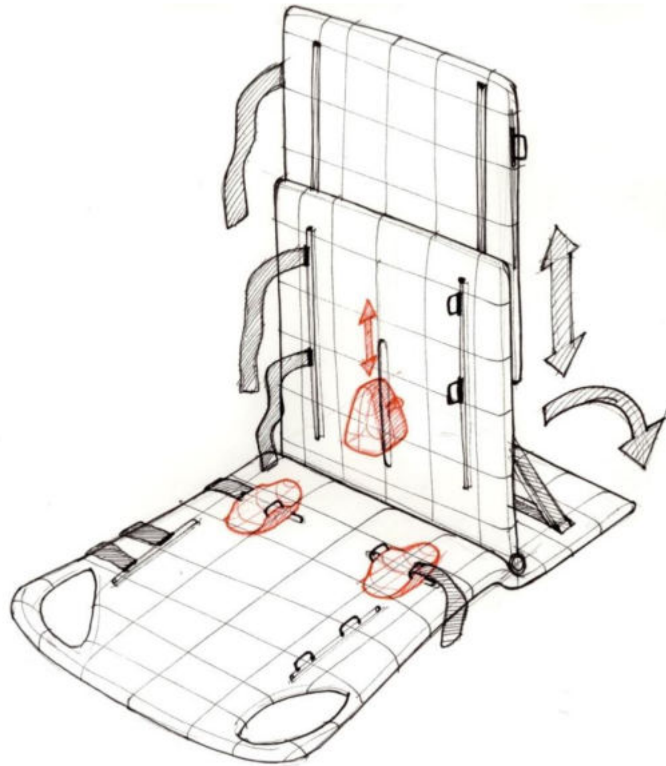


*Fig 9.8 concept2 positioning for standing, sitting kneeling*

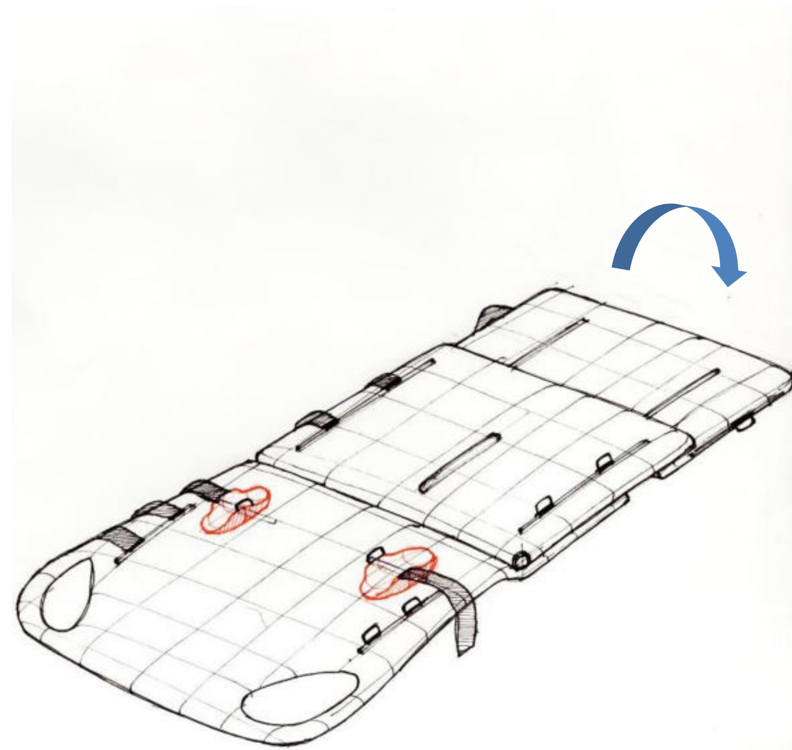
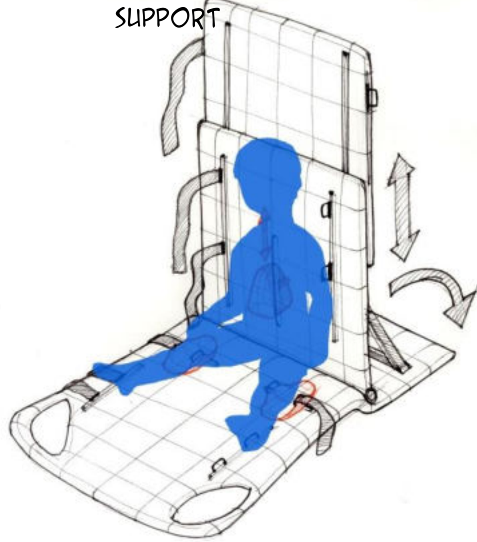
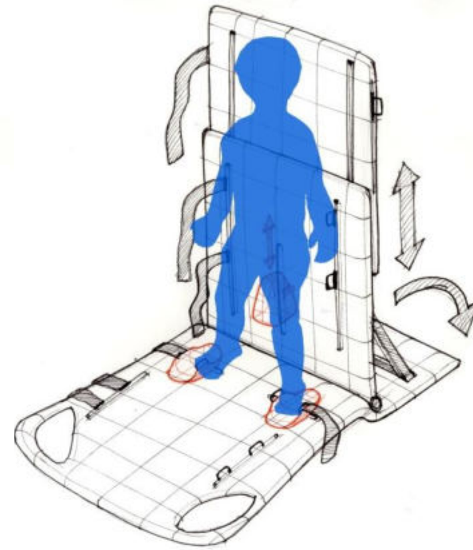
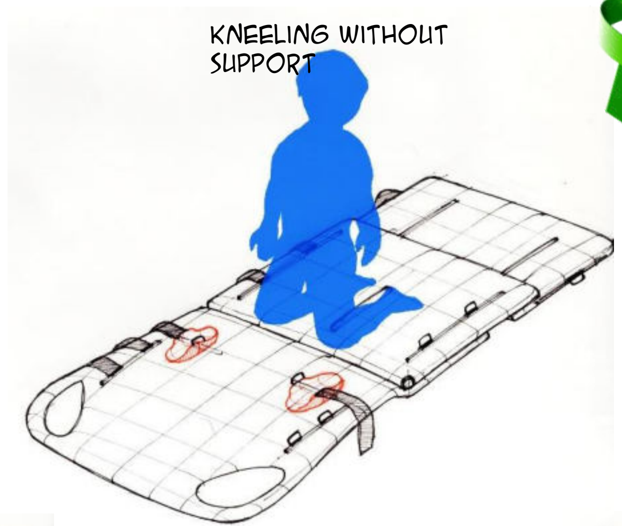


*Fig 9.9 concept2 positioning for supine, prone and quadruped*



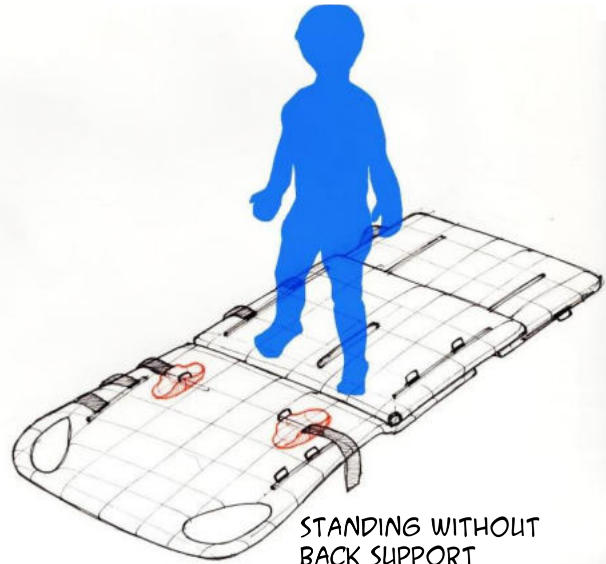
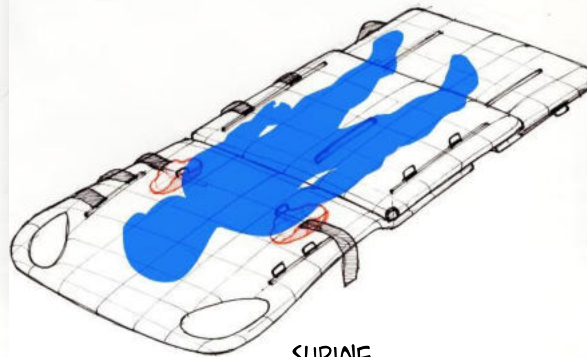




*Fig 9.10 examples for concept 2 positioning*



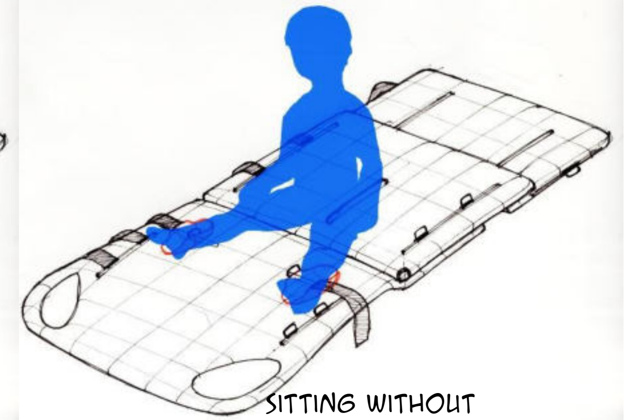



Fig.9.11 shows the stimulator part of concept 2. concept two is proposed to stand and operate and only with hand. Here, the mechanism given for gravitational ascending descending is a fulcrum-load-lever mechanism which will make it easy in operation. The lever pushes the spring down and the physiotherapist is in a better posture and better interaction with the child can be achieved.

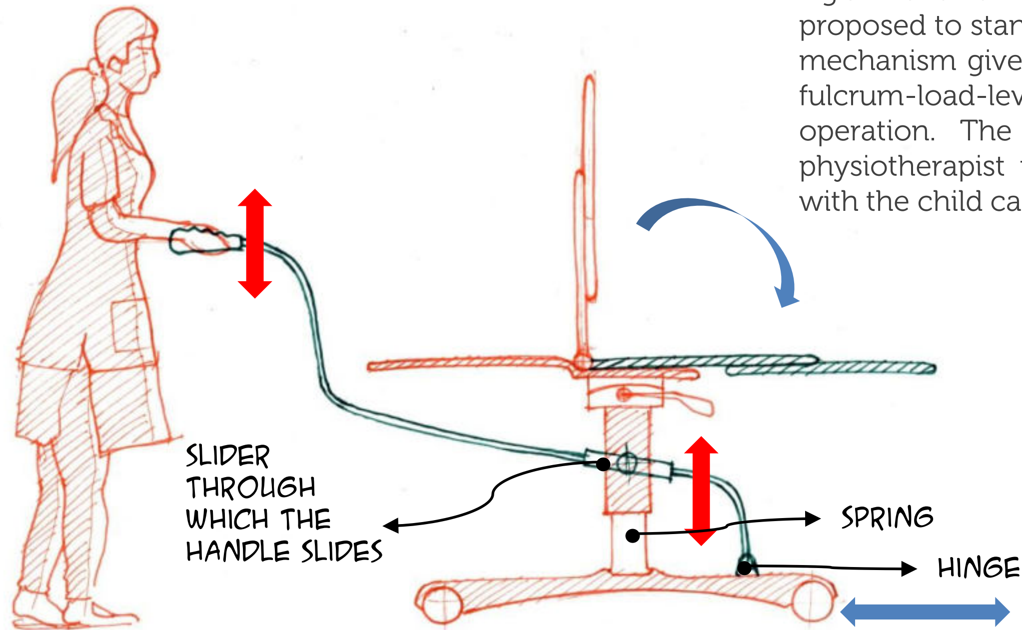



*Fig 9.11 concept 2:the stimulator part*

# 9.3. concept 3

### advantages

- Hanging vestibulator
- combines vestibulator 1 with vestibulator 2
- Motorised less effort needed in operation
- Can perform supine, prone, sitting, standing supine board, standing prone board and kneeling in forward-backward linear, forward-backward/side-to-side tilt, gravitational ascending-descending and spinning motions.
- Only one person required for the operation

### disadvantages

- Large and takes lot of space.
- Cannot be easily assembled and disassembled
- Difficult in changing from one exercise to the other
- Sophisticated mechanism.
- Bad interaction between therapist and child
- Cant have quadruped position in the platform

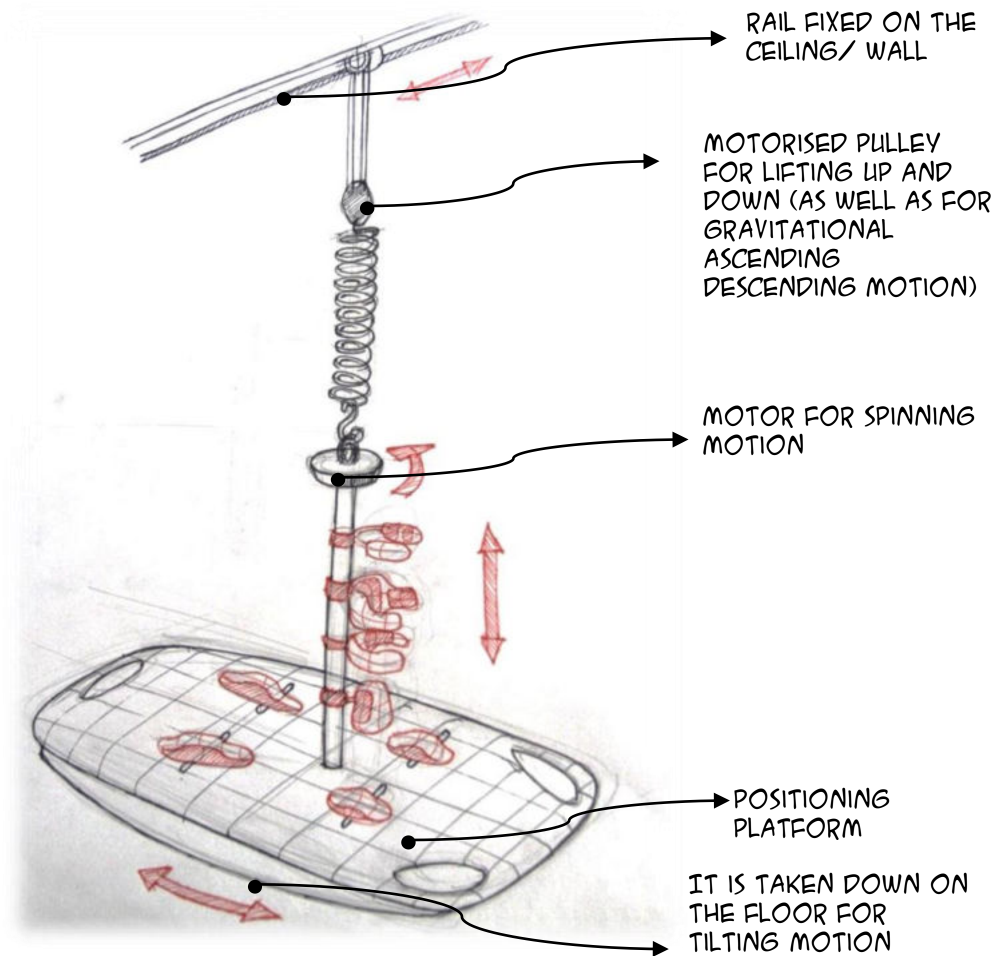



*Fig.9.12 child positioning part of the concept 3*

# 10. Concept evaluation

The concepts are evaluated on a system such that for each parameter, it divides 10 points between the concepts. For the concept evaluation, the concepts were presented to the physiotherapists in Centre for Child development, Haji Ali. More points were awarded to the concept that they felt better in each parameter.

| Parameters | Concept 1 | Concept 2 | Concept 3 |
|---|---|---|---|
| Safety for child | 5 | 3 | 2 |
| Comfort for child | 5 | 3 | 2 |
| Child-therapist interaction | 3 | 3 | 4 |
| efficiency | 4 | 3 | 3 |
| Ease of operation | 3 | 2 | 5 |
| compact | 4 | 4 | 2 |
| Less cost | 5 | 4 | 1 |
| Safety for the therapist | 2 | 3 | 5 |
| Therapist role for operation | 3 | 5 | 2 |
| Positioning part | 4 | 3 | 2 |
| Stimulator part | 3 | 4 | 2 |
| No. of people involved | 3 | 3 | 4 |
| Total | 45 | 41 | 34 |

*Table 10.1 concept evaluation*

Here, concept 1 wins and the positioning part of concept 1 is selected with the stimulator part of concept 2 to create the final model.

# 11. Anthropometric data

Anthropometry refers to the measurement of the human individuals. For every product designed for our use, anthropometric data are always a constraint for design. This data need not bee the average data of the population in a place. The data chosen is always to fit the maximum population in the product. For example, when a pen is designed, it is designed in such a way that the person with the smallest hand can also hold the pen. Data differs form place to place depending on the human race.

For the previous vestibulator, the author has conducted an anthropometric survey on 67 cerebral palsy Children in Maharashtra and Orissa. Due to the lack of time and permission in conducting a survey again, the data for the old design was borrowed for the redesign. The list of the data used is as show in the table below.

| Dimensions | Mean | ±SD | P95 | P50 | P5 | Max | Min |
|---|---|---|---|---|---|---|---|
| Age (months) | 47 | 17.51 | 69 | 42 | 15 | 72 | 12 |
| Body weight(kg) | 11.72 | 3.16 | 18 | 12 | 6 | 20 | 6 |
| Body height | 91.24 | 10.99 | 110 | 91 | 72 | 114 | 69 |
| Shoulder height | 72.65 | 9.80 | 86 | 72 | 58 | 90 | 51 |
| Armpit height | 64.51 | 9.04 | 77 | 65 | 50 | 80 | 44 |
| Span | 90.99 | 11.55 | 110 | 93 | 72 | 112 | 68 |
| Elbow span | 46.42 | 6.26 | 58 | 47 | 36 | 58 | 33 |
| Chest breadth | 17.96 | 1.83 | 21 | 18 | 15 | 22 | 13.5 |
| Armpit to knee height | 44.60 | 5.81 | 53 | 45 | 36 | 56 | 33 |
| Armpit to iliac crest height | 17.60 | 3.08 | 22 | 18 | 13 | 26 | 11 |
| Buttock height | 40.45 | 6.59 | 50 | 41 | 28 | 52 | 28 |
| Navel height | 49.36 | 7.30 | 60 | 49 | 37 | 62 | 35 |
| Calf height | 14.32 | 2.11 | 18 | 15 | 10.5 | 19 | 9.5 |

| Dimensions | Mean | ±SD | P95 | P50 | P5 | Max | Min |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Mid thigh depth | 8.18 | 1.27 | 10 | 8 | 6.5 | 11 | 5.5 |
| Trunk to knee height | 20.19 | 3.45 | 25 | 21 | 13.5 | 27 | 12 |
| Elbow height (sup. P.) | 53.72 | 7.75 | 64 | 54 | 40 | 70 | 38 |
| Elbow height (sit. p.) | 12.73 | 2.08 | 15.5 | 13 | 9 | 17 | 8 |
| Buttock to foot height | 47.16 | 6.92 | 58 | 48 | 33.5 | 60 | 33 |
| Navel height (sit. p.) | 11.96 | 1.81 | 14 | 12 | 9 | 17 | 8 |
| Abdomen depth | 12.29 | 1.37 | 14.5 | 12 | 10 | 15 | 8 |
| Shoulder H. (sit. p.) | 29.71 | 2.79 | 34 | 30 | 25 | 35 | 24 |
| Armpit height (sit. p.) | 21.62 | 2.31 | 25 | 22 | 17.5 | 26 | 17 |
| Knee height | 25.13 | 4.04 | 31 | 25 | 18 | 32 | 17.5 |
| Bi-deltoid breadth | 27.31 | 3.10 | 33 | 27.5 | 21 | 34 | 19 |
| Abdomen circumference | 48.51 | 4.80 | 57 | 49 | 41 | 59 | 39 |
| Arm length to fingertip | 36.01 | 4.64 | 43 | 37 | 27 | 44 | 27 |
| Foot breadth | 5.74 | 0.76 | 7 | 6 | 4.5 | 7.5 | 3.5 |
| Foot height | 4.11 | 0.62 | 5 | 4 | 3 | 6 | 3 |
| Abductor wedge upper part | 6.11 | 0.94 | 7.5 | 6.5 | 4.5 | 7.5 | 4 |
| Abductor wedge H. | 7.07 | 1.19 | 9 | 7 | 5 | 9.5 | 4 |
| Abductor wedge Lower part | 9.40 | 1.33 | 11.5 | 9.5 | 7 | 12 | 6.5 |
| Standing base | 10.74 | 1.11 | 12.5 | 11 | 9 | 13 | 8.5 |

*Table 11.1 the anthropometric data of 67 CP children from Maharashtra and Orissa.*

# 12. Final concept

The final concept is designed for complete manual operation with no compromise on the comfort, experience and safety of the child as well as the ease of operation of the therapist. Even though the comfort for the therapist is secondary, it is also considered. Because it has to be easy for them to operate so that they can spend their attention to the child than on the device. Secondly, the therapist should be in a good posture at the time of the therapeutic program or else it will affect their health.

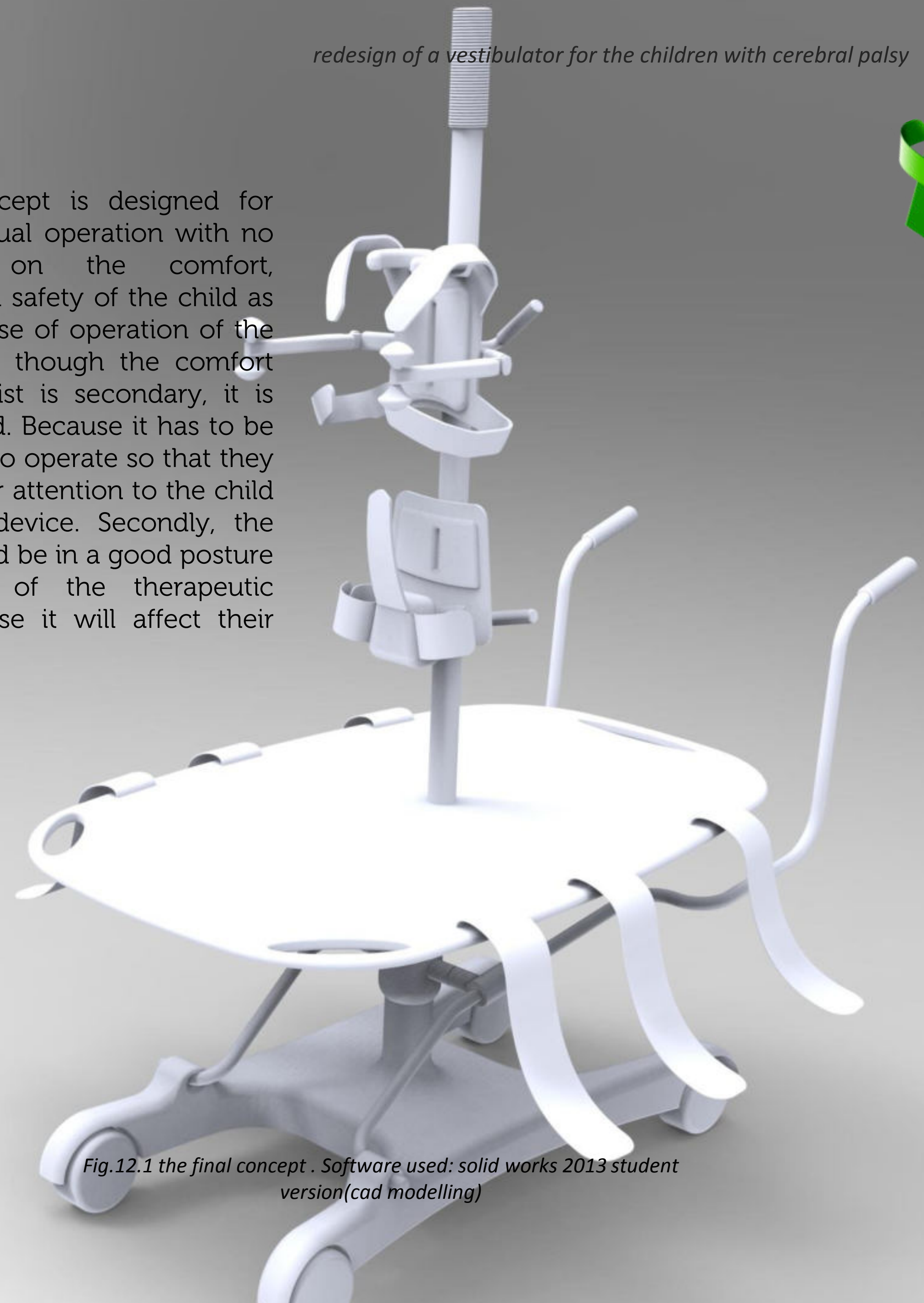


*Fig.12.1 the final concept . Software used: solid works 2013 student version(cad modelling)*

## 12. 1. cad model

*Fig.12.2 modelling assembly in solidworks 2013 with respect to the anthropometric data in table 11.1.*

## 12. 2. product details

*Fig.12.3 the final concept details of child positioning part . Software used: solid works 2013 student version(modelling) and keyshot4 (rendering)*

*Fig.12.4 the final concept details of child positioning part. Software used: solid works 2013 student version(modelling) and keyshot4 (rendering)*

HANDLE FOR FORWARD –BACKWARD/SIDE-TO-SIDE TILTING MOTION

SPINE (ALUMINIUM ALLOY)

HAND SCREW

HANDLES FOR GRAVITATIONAL ASCENDING DESCENDING/ LINEAR MOTION

HAND LEVER(STEEL)

*Fig.12.5 the final concept . Software used: solid works 2013 student version(modelling) and keyshot4 (rendering)*

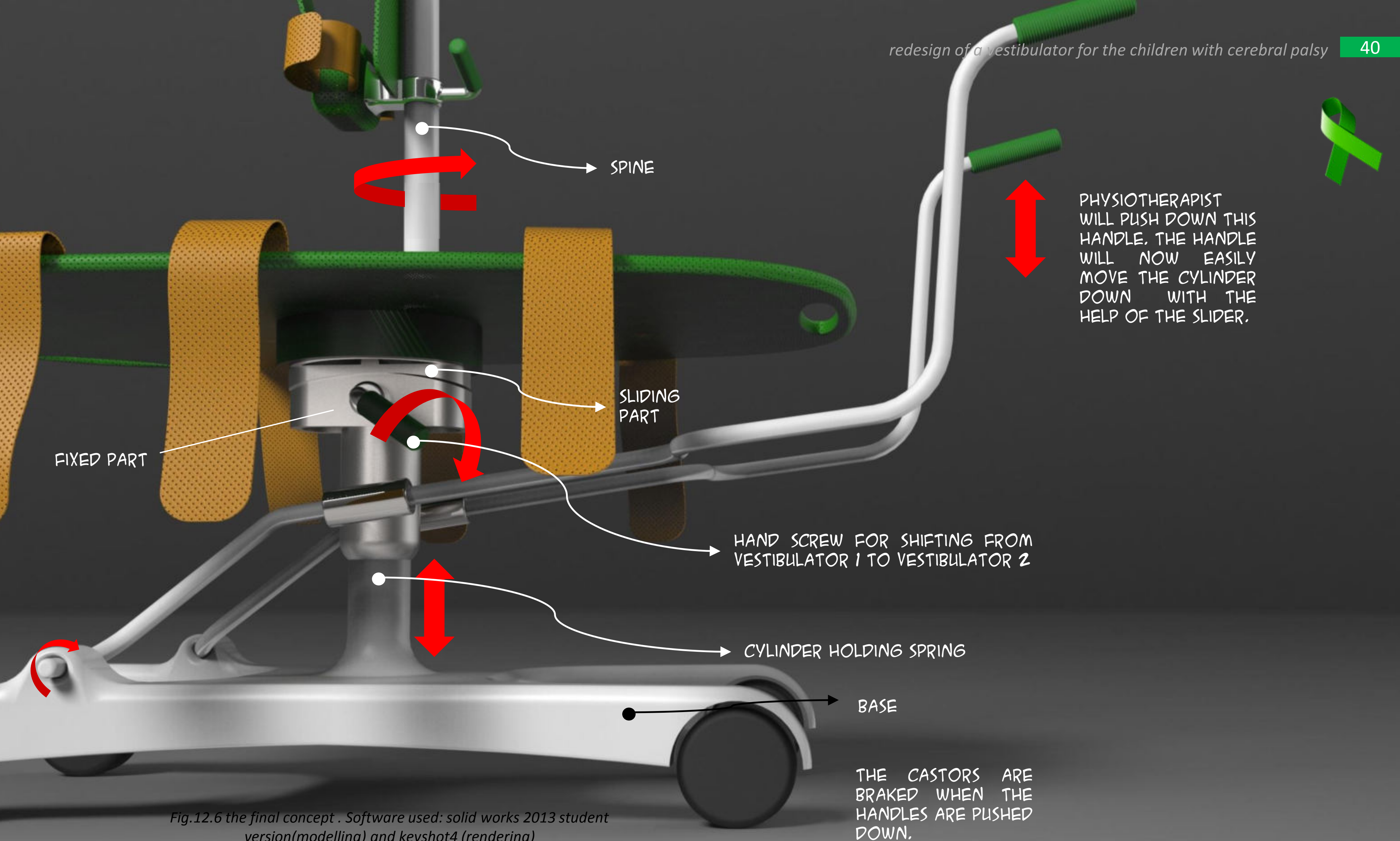



*Fig.12.6 the final concept . Software used: solid works 2013 student version(modelling) and keyshot4 (rendering)*

BREATHABLE STRAPPINGS

ERGONOMICALLY DESIGNED SO AS TO MAKE IT ADJUSTABLE TO KIDS OF 2-6 AGE

THE PLATFORM FOR POSITIONING THE KID IN QUADRUPED POSITION

SLIDING PART

*Fig.12.7 the final concept for quadruped positioning*

## 12. 3. therapy positions and motions

backward tilt motion for standing, kneeling, supine, prone and sitting positions

side-to-side tilt motion for standing, kneeling, supine, prone and sitting positions

forward tilt motion for standing, kneeling, supine, prone and sitting positions

side-to-side tilt motion for standing, kneeling, supine, prone and sitting positions

*Fig.12.8 therapy positions and motions*

gravitational ascending motion for standing, kneeling, supine, prone and sitting positions

gravitational ascending motion for quadruped position

gravitational descending motion for standing, kneeling, supine, prone and sitting positions

gravitational descending motion for quadruped position

*Fig.12.9 therapy positions and motions*

forward tilt motion for quadruped position

Sliding part

side-to-side tilting motion for quadruped position

backward tilt motion for quadruped position

side-to-side tilting motion for quadruped position

*Fig.12.10 therapy positions and motions*

# what's in the new design?

safety
child-therapist interaction
ease of operation
better experience for child
all therapy motions and positions
easy adjust for age 2-6
comfort
Better hand grip for child
1 therapist for 1 child
less space
collapsible

*Fig.12.11 the final concept . Software used: solid works 2013 student version(modelling) and keyshot4 (rendering)*

# The Prototype
(1:3 scale)

Fig.12.12 the fully functional prototype (scale 1:3)

# 13. Comparison

The old design is compared with the new one on a scale of 10 for the following parameters. For the comparative study, the physiotherapists from Centre for Child Development, Haji Ali, Mumbai were consulted.

### 1. Safety

In the old design, the idea of the research was to find a better way to stimulate the vestibular system of the children with cerebral palsy and the vestibulator was the end product of it. The weightage given for designing the product was much less compared to the research in vestibular stimulation. So the safety considerations were much less in the design. Even though there were support in the form of strappings, they were not enough to support the child during the therapy. For example, an ataxic child when strapped to the vestibulator, tries to pull himself/herself out of that in fear and could result in injuries to various body parts. The old vestibulator had sliding back support in wood to what the child hits the head in fear. So there was a need for soft cushioned supports that would support the neck well. And good supports for legs were also lacking in the design.

### 2. Child-therapist interaction

Child therapist interaction is much necessary for supporting and urging the child to make him do the activities and exercises. In the old design, the therapist had to put lot of attention into the device because of the improper supports and he/she needed to put lot of effort in operating the vestibulator. So this reduced the interaction between the child and therapist. So considerations were given in making the product easier to operate and with good supports so that there is a better child-therapist interaction.

### 3.Space consumption

The physiotherapists in the Centre for Child Development, Mumbai, where the old vestibulator was donated, stated that the vestibulator takes up a lot of space. Since the vestibulator was designed into two parts, there was a need for combining both into one. And the redesign does not vary much from the actual dimensions of the old once since it is also designed with the anthropometric data of the children within the age group 1-6. But it reduced much of the space needed by combining the two into one.

4.Ease of operation

It should be easy for the therapist to perform the therapy because each therapist will have to treat lot of children all day long. And most of the time the therapist will have to carry most of the bodyweight of the child during the therapy. So focus was given to reduce other stresses to the therapist like the effort required to operate the vestibulator, changing the child from one position to other and strapping the child. In the old design, the therapy requires more persons at a time and it has been reduced to one therapist in the new design. But the redesign considers the presence of the parent to make the child better and comfortable.

5.All therapy positions and motions

The old design as well as the redesign addresses every positions and motions of the vestibular therapy. Interestingly, this design combines  two old vestibulator designs.

6.Adjustability for age 2-6

The old design had two sliding vertical plates for adjusting to the height of the child but when we adjust sliding vertical plate, the strappings that passes through that may not come into the comfortable area of all children. There was difficulty in adjusting between different exercises in the old design and it consumed lot of time. All these have been solved in the new design.

7.Collapsible

Even though there are lot of collapsible parts in the old design, there were difficulty in collapsing it . The old design had two pillars for holding the two sliding vertical plates onto which the child is strapped for standing position. So if the child need to stand with no support, the therapist needed to remove the vertical plates and then followed by the pillars. The new design comes with a single central spine which can be just twisted to unlock from the positioning platform.

8.Comfort for child

As mentioned earlier, the old research was to find an effective therapeutic program and the vestibulator being a product of that, the comfort of the child was not addressed in it. The new design comes wit a better soft 5 point harness strapping that would make the child feel comfortable.

9.Better hand grip for child

The old design came with the flat tray and the Abdominal Cut Out (ACO)tray for resting the while having the therapy in standing prone and supine positions respectively. But it is difficult for the child to hold to the cylindrical/flat grips. The trays being heavy, it was also difficult for the therapist to adjust it according to the child. So the new design comes with a better hand grip as shown in fig.12.4. the handle in the new design can be switched from one direction to the other thus eliminating the need of flat and ACO trays.

10.One therapist for one child

As mentioned earlier, the old design requires 2-3 people at a time to operate and the new design requires only one therapist for one child.

11. Better experience for child

It is very important to make the therapeutic program enjoyable for the child. The design should make the child feel that it is not a torture device but a device to have some fun. The old design could not give a good experience to the child. So comfort, colour,  form of the device has a great role in in giving a better experience to the child. This is expected to achieve in the prototype.

| old | parameter | new |
|---|---|---|
| 5 | safety | 8 |
| 6 | child - therapist interaction | 9 |
| 5 | Space consumption | 8 |
| 3 | ease of operation | 7 |
| 10 | all therapy motions and positions | 10 |
| 5 | easy adjust for age1-6 | 8 |
| 6 | collapsible | 8 |
| 3 | Comfort for child | 8 |
| 5 | better hand grip for child | 8 |
| 5 | 1 therapist for 1 child | 9 |
| 5 | better experience for child | 7 |

*Fig.13.1 the comparison between old and the new design*

# 14. Dimensional drawing

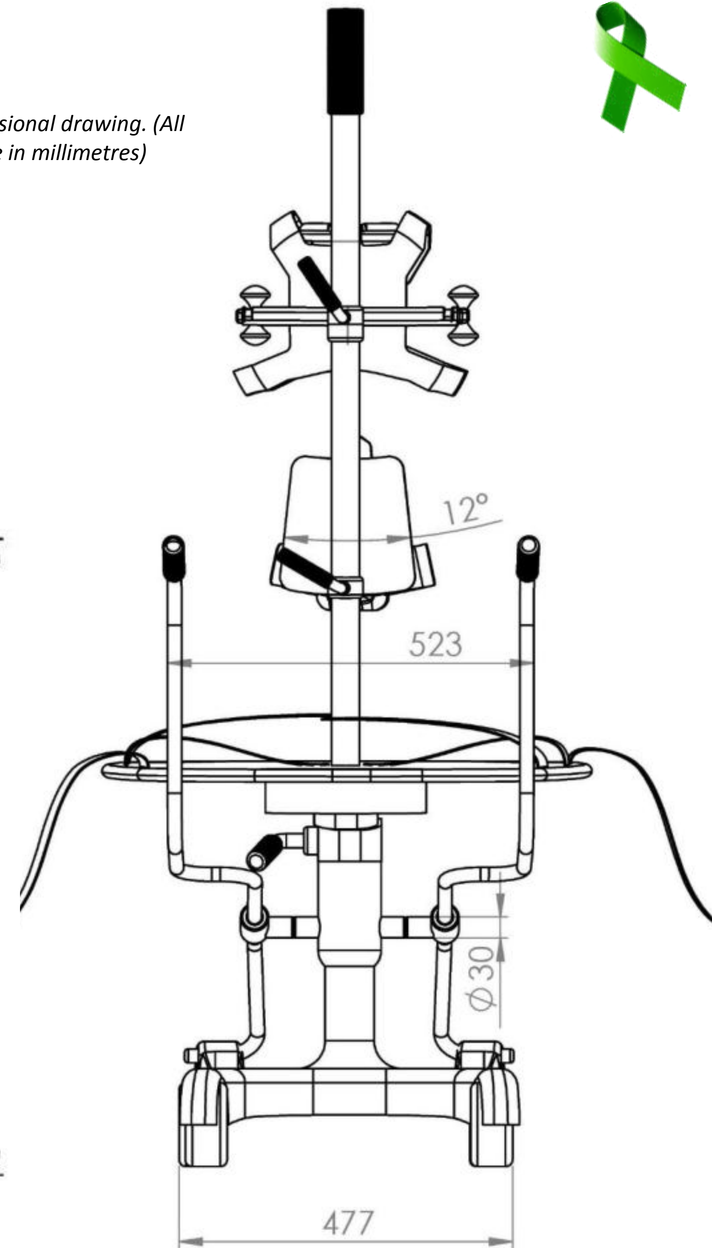



*Fig.14.1 the dimensional drawing. (All dimensions are in millimetres)*

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*The green ribbon is a symbol used to show support and create awareness for those suffering from various illnesses*

to make them smile....