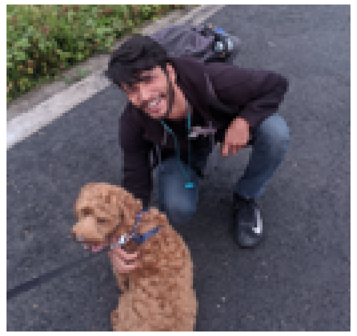
WHEEL+

AN INTEGRATED WHEELCHAIR EQUIPMENT DESIGNED FOR CAREGIVERS OF DIALYSIS PATIENTS TO TRANSFER THEM AFTER THEIR BLOOD PURIFICATION

Final Major Project
Harshil Jogi, MSc, Product Design Engineering

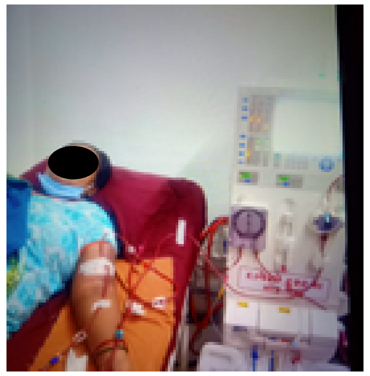
BACKGROUND & USER RESEARCH

It all started with a **Night Walk Discussions...**



I started my Initial research on Blood Dialysis (procedure performed on the patients whose kidneys stops functioning) after one of my very good friends mentioned how, his former landlords in Mumbai suffered due to his dialysis sessions during our night walks. We were discussing how a designer could intervene in this traumatic procedure.

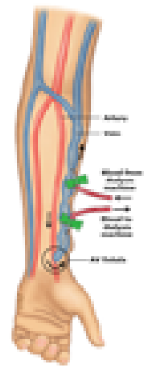
My further investigation..



I talked with few of my relatives, friends and neighbours who had an experiences of Dialysis. I discovered how basic daily activities like lifting heavy items, driving or public transportation could get really difficult while being on dialysis. However to really look close into the patients lives, i reached out to the renal units in Glasgow. I also joined few facebook pages and dialysis patient's group where i could directly connect with Dialysis patients and some doctors.

INITIAL DESIGN PROBLEM 1 & PROBLEM 2:

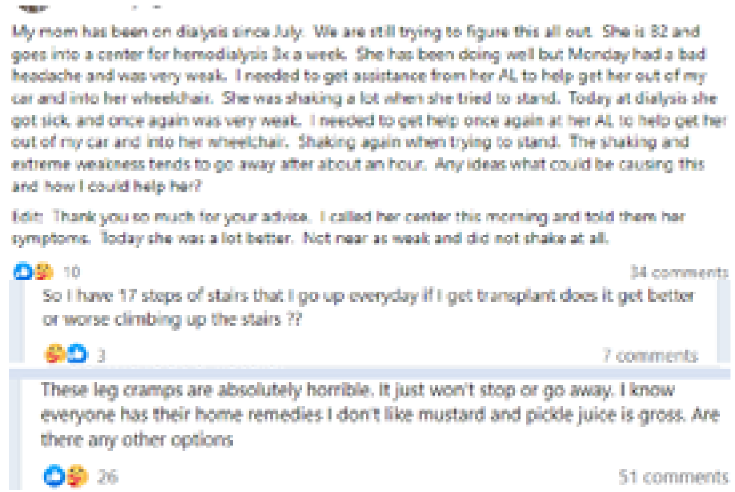
Initially, my first design proposal was the minimise the complications and restrictions faced by dialysis patient due to Fistula. The foremost user insight that led me to this problem were by some Indian Dialysis patients who said that they cannot use their Arm in which fistula is installed. This myth was completely bursted when i talked with patients from Philipines, USA and UK; according to whom Fistula never restricted them to use their arm. However, i noticed that the doctors in India still preferred their patients not using their Fistula Arm.



On further research, i realised the real reason doctors don't advice to lift weight is not the fistula but a chemical called Ketonine, which is produced in the body when any muscles tear up. It is filtered from the body through Kidney or more dialysis. This defined my **2nd Problem** which was about Home-Hemo Dialysis, and why patients are skeptical about it. To research this, i needed an access to renal units, Dialysis patients home and support from kidney care giving organizations

A **turning point and Refocusing myself**..

After almost trying for a month to get an access of a renal unit to observe the daily life of a Dialysis patient, i was denied due privacy reasons. Thus, i decided to shift focus on the other stakeholders that are involved in the life of Dialysis patients like Nurses and Caregivers. I started putting pre-scripted posts on Facebook to connect with Dialysis patients and their caregivers. From the online chats and phone calls with the patients and their caregivers, i discovered, Dialysis can leave patients crippled. Caregivers need to assist their patients in basic activities like climbing stairs, moving to a toilet or a car or even catch a bus. These information helped me for my final design challenge.



My mom has been on dialysis since July. We are still trying to figure this all out. She is 82 and goes into a center for hemodialysis 3x a week. She has been doing well but Monday had a bad headache and was very weak. I needed to get assistance from her AL to help get her out of my car and into her wheelchair. She was shaking a lot when she tried to stand. Today at dialysis she got sick, and once again was very weak. I needed to get help once again at her AL to help get her out of my car and into her wheelchair. Shaking again when trying to stand. The shaking and extreme weakness tends to go away after about an hour. Any ideas what could be causing this and how I could help her?

Edit: Thank you so much for your advice. I called her center this morning and told them her symptoms. Today she was a lot better. Not near as weak and did not shake at all.

10 · 34 comments

So I have 17 steps of stairs that I go up everyday if I get transplant does it get better or worse climbing up the stairs ??

3 · 7 comments

These leg cramps are absolutely horrible. It just won't stop or go away. I know everyone has their home remedies I don't like mustard and pickle juice is gross. Are there any other options

26 · 51 comments

Key User Insights...

Following are the key user insights colected from interviews.

"My mom can't get up and use walker or wheelchair for restroom after/during dialysis".

"It is very difficult to transfer my mom into the car from wheel chair".

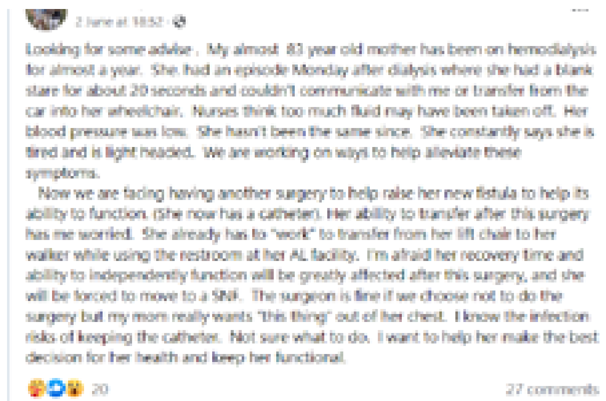
"Cannot climb stairs after Dialysis".

"I have to reach bus stand very early as I can't run to catch bus".

"My body swells a lot, leg swells and aches a lot which makes walking difficult".

FINAL DESIGN PROBLEM

As a final design Challenge, i decided to solve the problem of transferring the Dialysis patients after their blood filtration process. This was inspired by an incident faced by one of the caregivers i talked with. I discovered that, body pressure of the patients drops suddenly after Dialysis, leaving the patients feeling Nauseated, Dizzy and they might faint. It could be a very strenous task for their Caregivers, to move them between Renal unit and car.



2 June at 18:52

Looking for some advise . My almost 83 year old mother has been on hemodialysis for almost a year. She had an episode Monday after dialysis where she had a blank stare for about 20 seconds and couldn't communicate with me or transfer from the car into her wheelchair. Nurses think too much fluid may have been taken off. Her blood pressure was low. She hasn't been the same since. She constantly says she is tired and is light headed. We are working on ways to help alleviate these symptoms.

Now we are facing having another surgery to help raise her new fistula to help its ability to function. (She now has a catheter). Her ability to transfer after this surgery has me worried. She already has to "work" to transfer from her lift chair to her walker while using the restroom at her AL facility. I'm afraid her recovery time and ability to independently function will be greatly affected after this surgery, and she will be forced to move to a SNF. The surgeon is fine if we choose not to do the surgery but my mom really wants "this thing" out of her chest. I know the infection risks of keeping the catheter. Not sure what to do. I want to help her make the best decision for her health and keep her functional.

20 · 27 comments

REFINING THE DESIGN CHALLENGE

User Personas: Caregiver and Patient

Summarising the interviews and research, a user persona was created for the project.

Non-Professional Caregiver (Daughter/Wife/Relatives):

Name:	Donna
Relation with Patient:	Daughter
Age:	Mid 40's
Emotion:	"It is very difficult for me to transfer my mom from wheelchair to car after Dialysis"

Patient Characteristics:

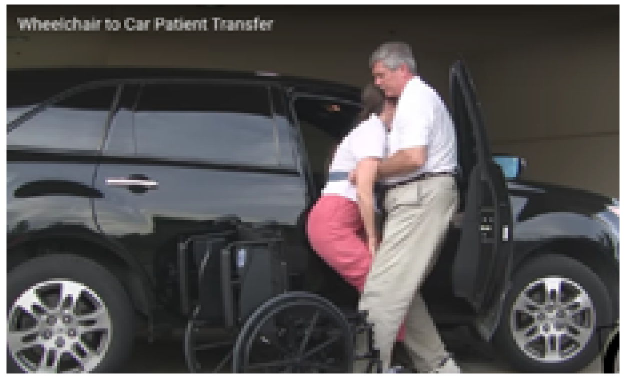
Weight:	Donna
Condition:	Can stand up but unable to walk properly, nauseated, dizzy, low blood pressure, risk of falling
Use of Wheelchair:	Twice a Day, Three time a week when dialysis need to be performed

Transfering Patients from Wheelchair to Car:

The following picture shows how patients are manually transferred by professional caregivers.

1. Tie Belt/Rope on patients Waist
2. Lift the patients with the waist belt

3. Block patients knees and legs with your's if needed



4. Rotate the patient's body against the car seat
5. Watch out for Patients Head

6. Put patients body over seat and push in

Wheelchair:

The wheelchair's used for patients are generally rear steered and doesn't necessarily have to be foldable. However, except foldability, the rest of the structure is almost same as a Manual wheelchair. In this project, a manual wheelchair has been used as it was easy available.

Patient's Wheelchair

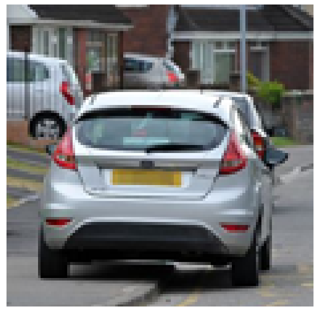
Manual Wheelchair

User Scenario:

Following are the environments that a car could be paked in during a transfer of patient.

Smooth Parking surface

Parking near the pavement

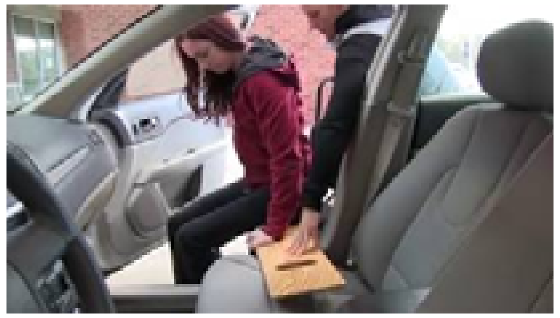


Half pavement parking

Parking near uneven roads

Current Market and Passive Equipments

Equipment in the current market does the job of transferring patients to the car well, but are found to be passive in nature. These solutions are bulky and are and external attachment need to be carried by patient's caregiver to transfer patients. I also looked at hacks by Disabled people, but that might not work as patients might not have energy to self transfer into the car.



BIOMECHANICS OF TRANSFER

Refined Design Challenge:

To Design an
Integrated Active Wheelchair Solution
that would allow
Non-Professional Caregivers
to be able to
transfer weak Dialysis patients easily from Wheelchair to Car

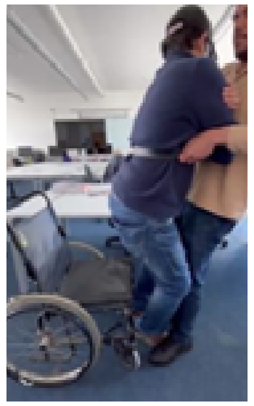
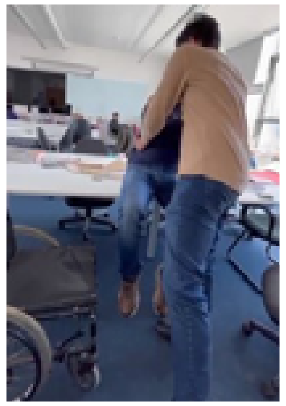
Physics in Transferring patients:

The five main factors that largely impact the transfer are:

1. Centre of Gravity of Patient **2. Height of Caregiver** **3. Height and Weight of Patient**
4. Height of Wheelchair **5. Height of Car's seat**

1. Centre of Gravity:

Centre of Gravity plays a very vital role in the transfer of patient from wheelchair to car. To realise it myself, i tried lifting some of my friends and failed miserably at the first try!!

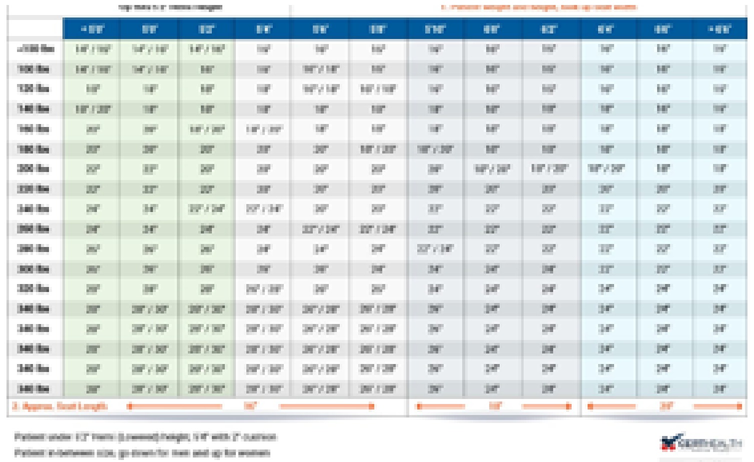
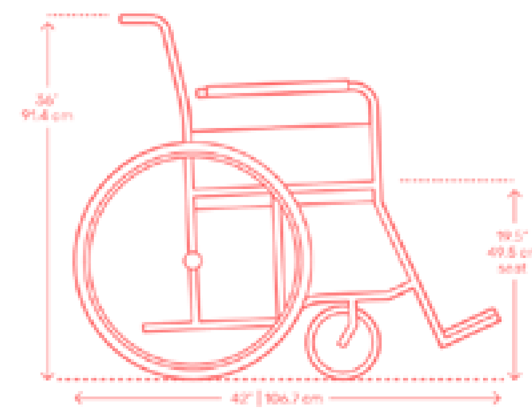
Outcome:
It can be observed, that the centre of gravity of patient and caregiver must balance over the focal point which is at caregiver's feet.
Closer the centre of gravity from the focal point, better will be the control. Also, there must be something for the patient to hold for smooth and stable transfer.

2. Height of Caregiver: Impact of hip-length

I asked my other friends to perform the same activity to observe how they do it. It was observed that, people with more leg length could utilize their hip force over the focal point to lift the the patient up, however, shorter people seem to struggle.

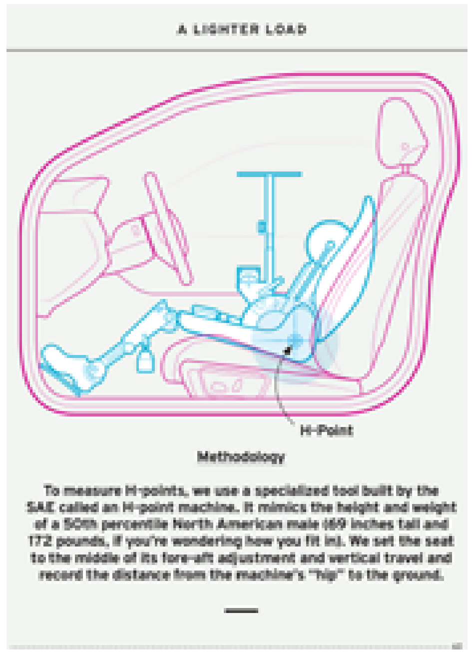

3. Dimension of patients & 4. Height of Wheelchair

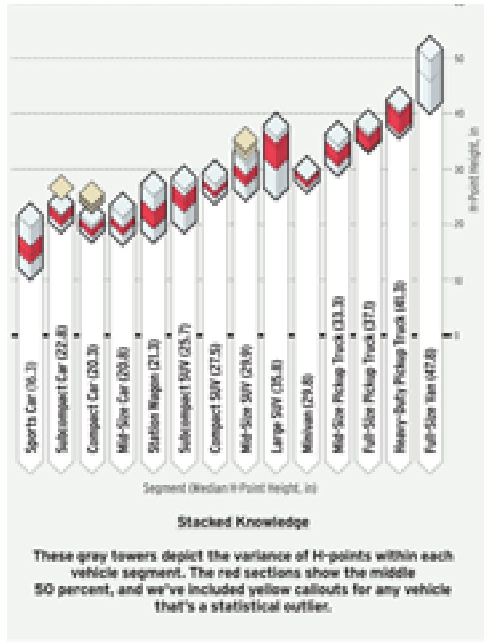
Height of Wheelchair is directly dependent on the dimensions and weight of the patient. But, since the user and patient use the wheelchair only 6-8 times a week (before and after dialysis), importance of these factors reduces.
The table below depicts size of wheelchair based on patient's height and weight. The drawing on the right mentions the size of the wheelchair used in the project.

5. Height of Car's seat

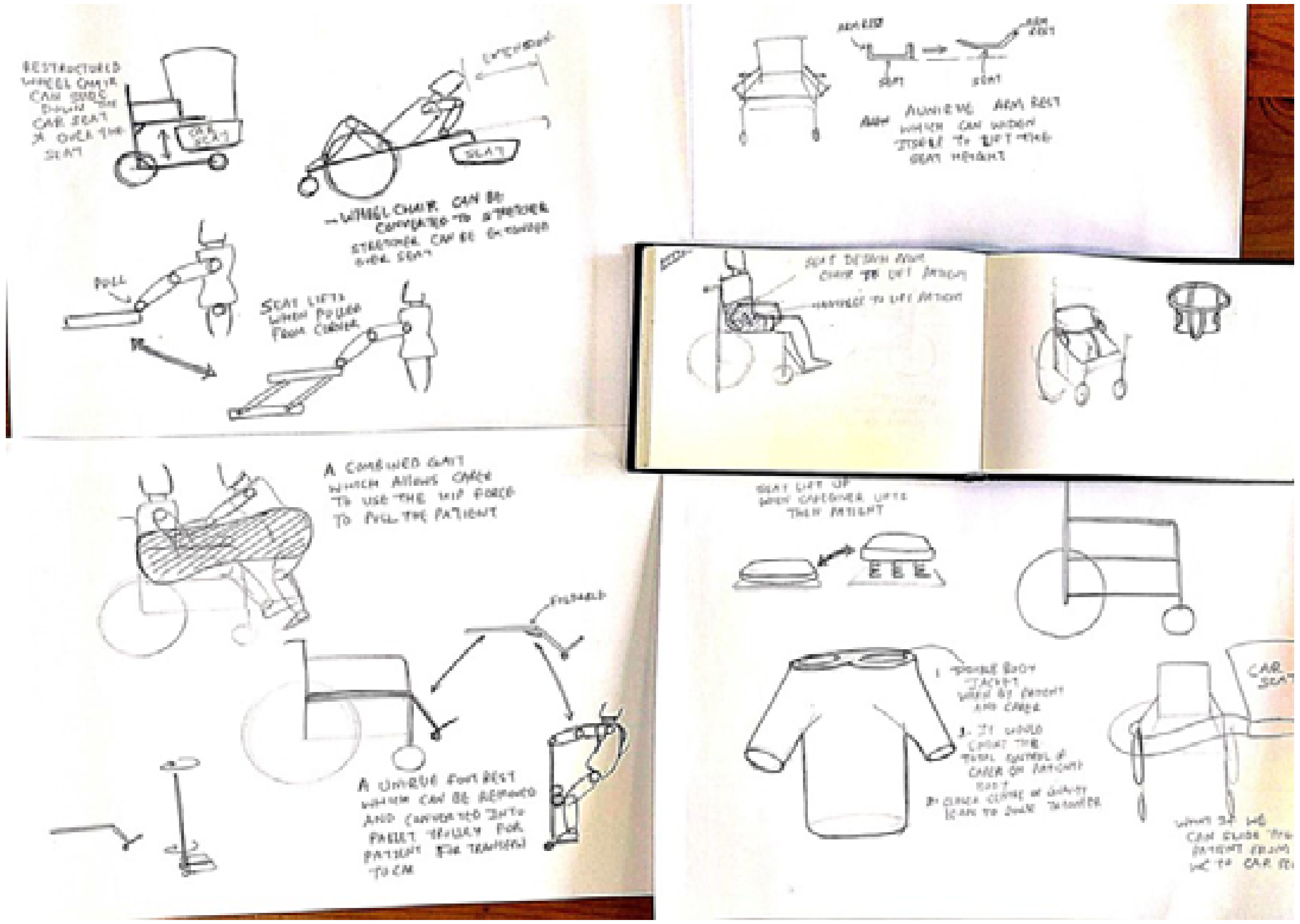
Car's seat height from the ground is measured in terms of H-point (Hip point). Domestically used cars include Sedans, Hatchbacks, Mini and Semi SUVs have their H-Point between 400 mm and 750 mm from the ground. Large SUVs, Flat sport cars and Trucks are neglected in this project.
The image below mentions the H-Points of different types of vehicles in Inches (1 inch is equal to 25.4 mm for reference).
The two cars used in this project had H-Points at 700mm (charcoal) and 620mm (white) respectively





CONCEPTUALIZATION & EVALUATION:

With rapid ideation 10 concepts were generated. These concept are explained in more detail in the Working Design Journal.



Concept Evaluation:

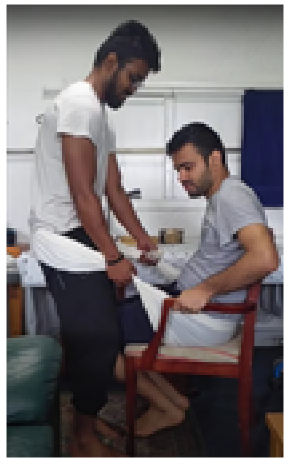
The concepts were then evaluated by keeping in mind the following aspects.

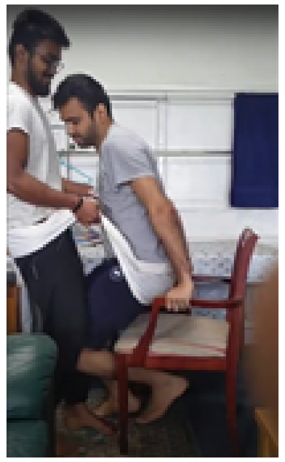
Leverage to Reduce force of lifting

Pivot Smoothly

Something to hold for Patient

Integrated Active Wheelchair Solution





Out of 10, 2 preffered concepts were then simply role played with the friends who had experience of living with Wheelchair patients.

The first concept was to use the body weight of the caregiver and using the hip force to help patient standing up.

Outcome:

- If patient won't have energy in their leg, they might just fall.
- The top figure show the patient applying the force on the Arm rest of there chair to support car, however, instead of standing up, vertical force of arm combined with the horizontal force by caregiver disbalanced both of them and made the prcedure more strenous!!

For the next concept, i borrowed a sack barrow trolley from the GSA to roleplay the whole scenario. A temporary Car's door was created using a piece of foam, where as a table of the exact car's seat height was used to imitate a car.

Outcome:

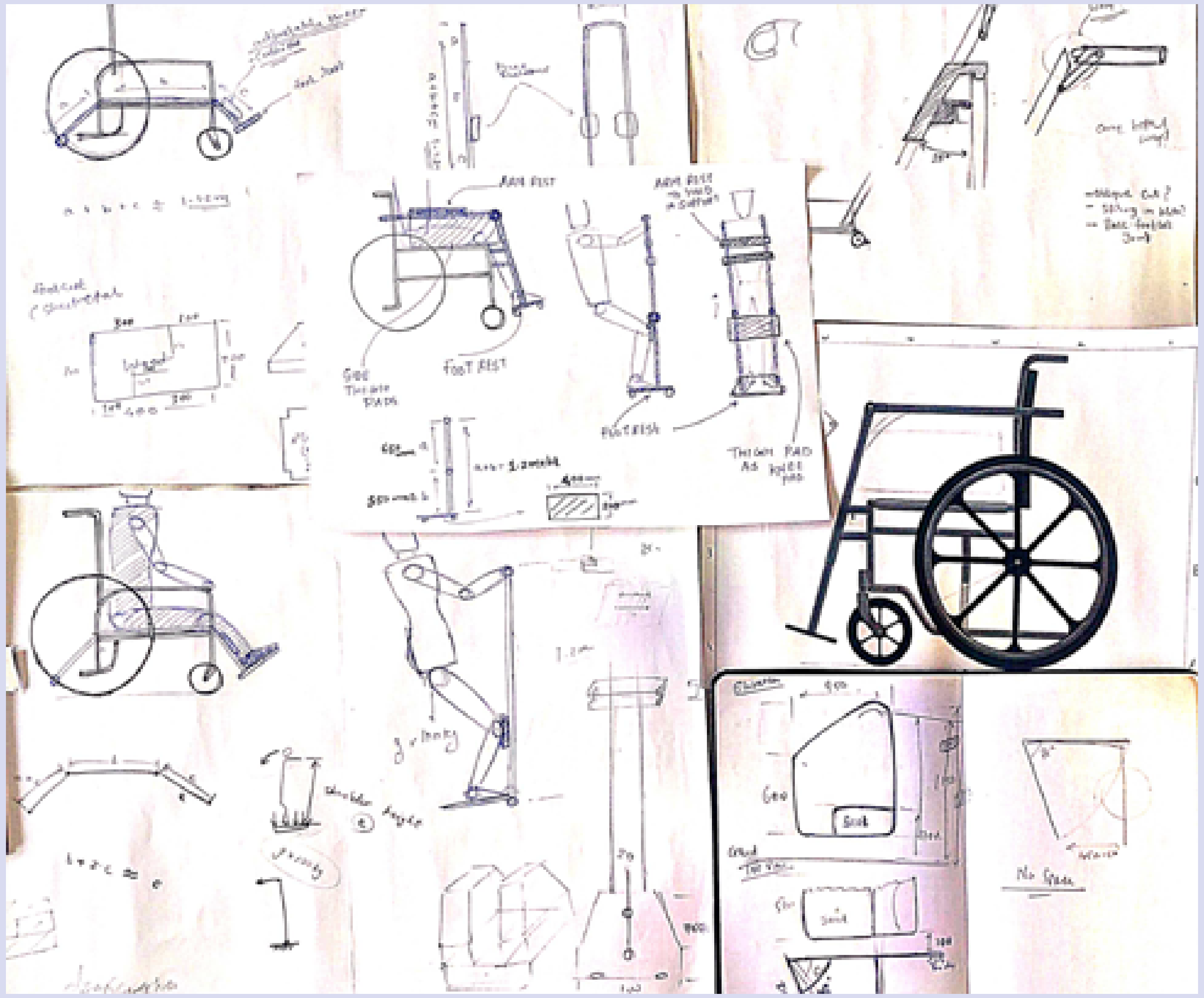
- Knee support was found to be an important factor from the patient's perspective.
- For a caregiver, vertical pulling handles were preffered more than the horizontal. It can be observed in the bottom right pictures where one of my friends is trying to lift me by Pulling vertically.
- The big wheels of the sack barrow required a lot of force, and made it very difficult to rotate a patient against the car's seat. Putting a castor wheel with brake on the front was one of the suggestions preffered by my classmates.
- The last image demonstrate the combination of both the concepts, the one with a cloth gait belt and a sackbarrow. But it seemed to be not much helpful.

CONCEPT DEVELOPMENT AND ANTHROPOMETRY

Preffered Concept:

The final preffered concept was the one inspired by a sack trolley. The major challenge was to integrate that structure into a wheelchair frame to convert it into an active solution.
The initial idea was to integrate the *Footrest* and *Antitippers* to make a structure which would work like a sack trolley.

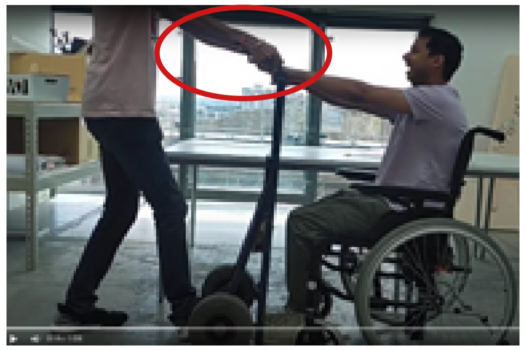
The idea was later changed from a combination of ~~***Footrest + Antitippers***~~ to ***Armrest + Footrest***.
The footrest would have have castorwheels with brakes to support, move and later rotate the patients towards the car.

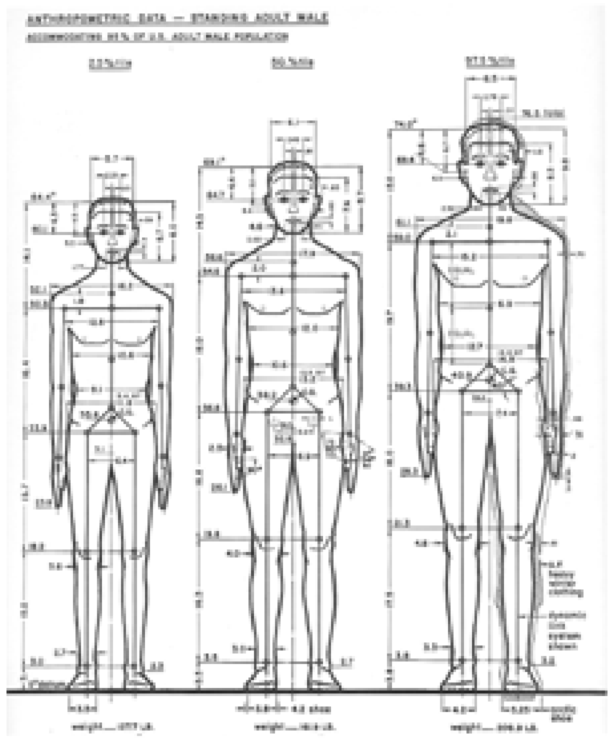


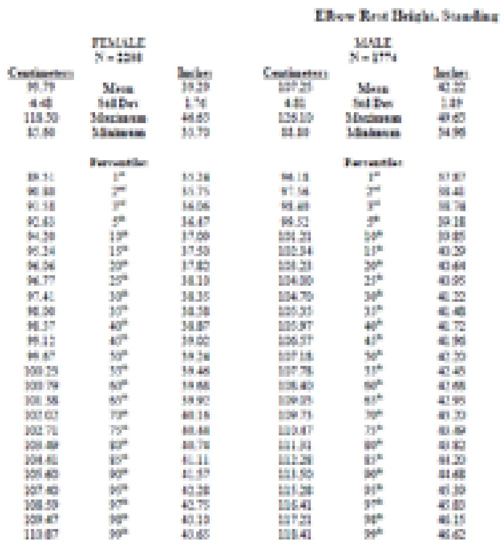
Anthropometry:

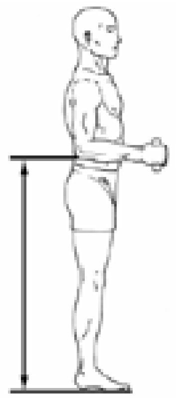
It was observed during the user concept evaluation that, shorter caregivers were required to use more strength to move the patient, because the pulling point was almost inline to their shoulders, which would require them to bend their elbows.
Taller caregivers had their elbow straight and more control over the patient's weight.

To overcome this issue, i used anthropometric data. A structure with a pulling point range from at approximately 1 - 1.2 metre from the ground would suit the 95 %ile of people to be able to pull without bending their elbow. Where as reduction in leverage can be overcome by foot force over the footrest.






Elbow Rest Height, Standing



Dimension of the footrest should minimum be 400 mm * 150 mm to match the the dimensions of wheelchair frame with required leg space.

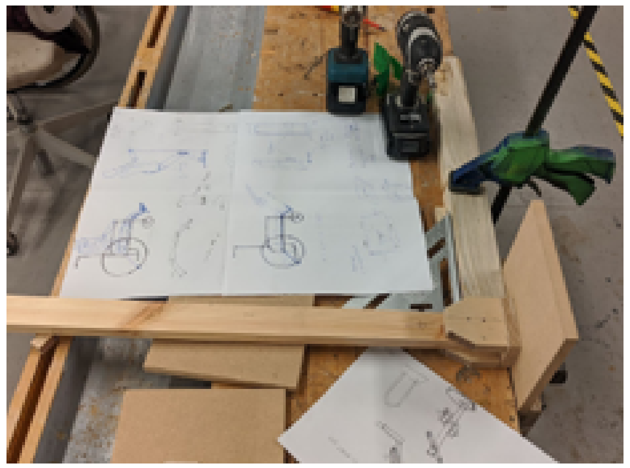
PROTOTYPING & INITIAL USER TESTING

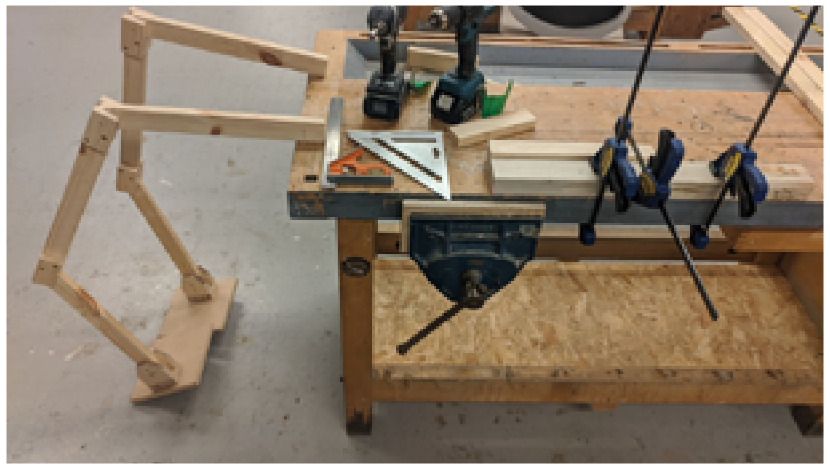
Scaled Models:

To keep in touch with the ergonomics and the size difference between different car seat height and a wheelchair seat height, i created a miniature 1/10th scale model of my wheelchair concepts.
To create this setup, a Manequin of 1/10th size of 6 feet 10 inch man was used. A wheelchair was selected using the chart mentioned in the above section and a 1/10th scale model was 3d printed.
A car sketch of Audi A3 sedan was printed, in which different lines indicates the H-points ranging from 450mm (lowest (green)) till 700mm (highest (red)).
Wheelchair seat had the height of 450, which exactly matches the Green line on the car.

Satisfying my passion for Carpenty..

Fool scale wooden models were created to analyse the User Journey and Ergonomics.
The model shown has 3 links in each arm, which was reduced to two links in the later stage of design because this model was optimized for the rejected combination of Footrest & Antitippers.
The total height of the model was **1.2 Metre** which seemed to be perfect for even some of my small heighted Friends.





User testing:

Full scale model was then given to my users who roleplayed with the sackbarrow.

Outcomes:
The most prominent complaint was regarding the **Kneepads**. One of the user preferred a bigger knee pads however, one wanted to have a singular knee pad for both the legs of equipment.

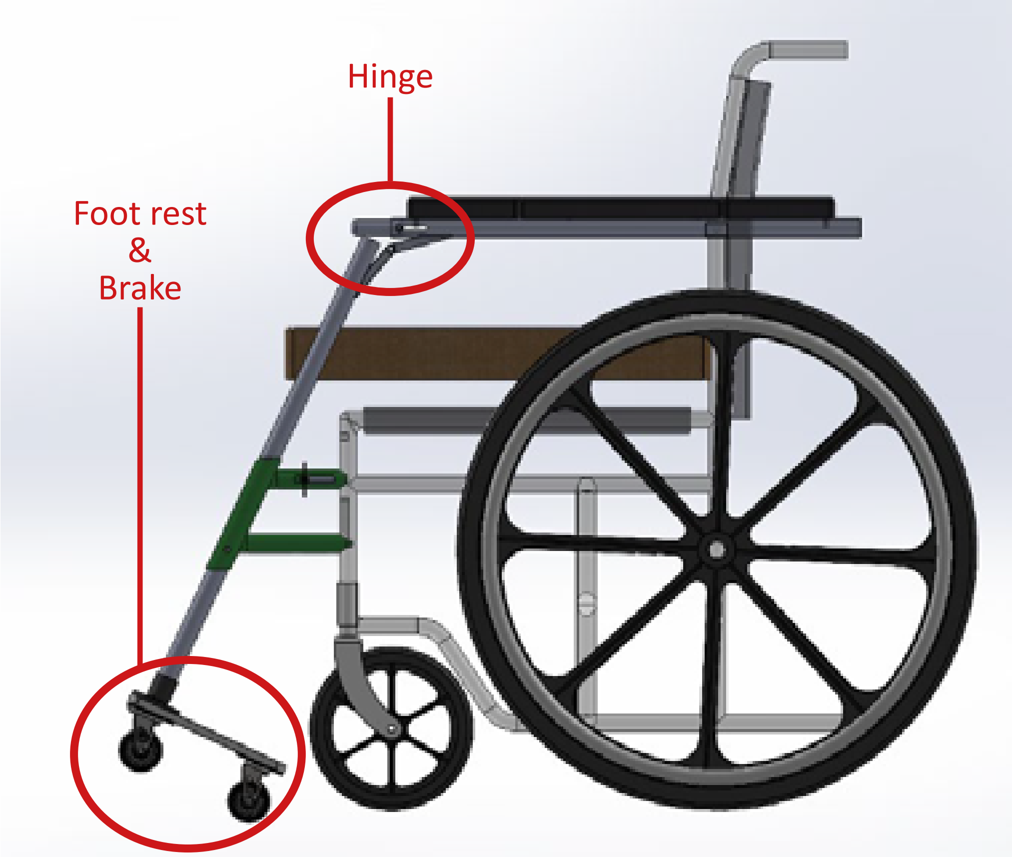
Outcomes:
The other complain was difficulty to pivot without wheels which weren't assembled then and Arm rest. one of the patient-users complained about the armrest to come in the way of holding the equipment. It was difficult to hold the equipmen's leg as well as the arm rest padding.
Both the mentioned issues were being dealt with in the later stage of design.

A long Day with Tutors....
A full scale mockup scene was created during the tutorial in the studio using a sack barrow, wooden prototype and Chair, Desk and foam as car's body.

Outcomes:
Unlike the other users, the tutor found this design to be **unrealistic and unreliable**.
According to my tutors, the design wasn't safe because of too many joints and links.
This made me rethink the whole model and comeup with a different models, joints and prototypes.
I was also been asked to consider the engineering aspects and rethink the user journey.

PROTOTYPING: STAGE 2

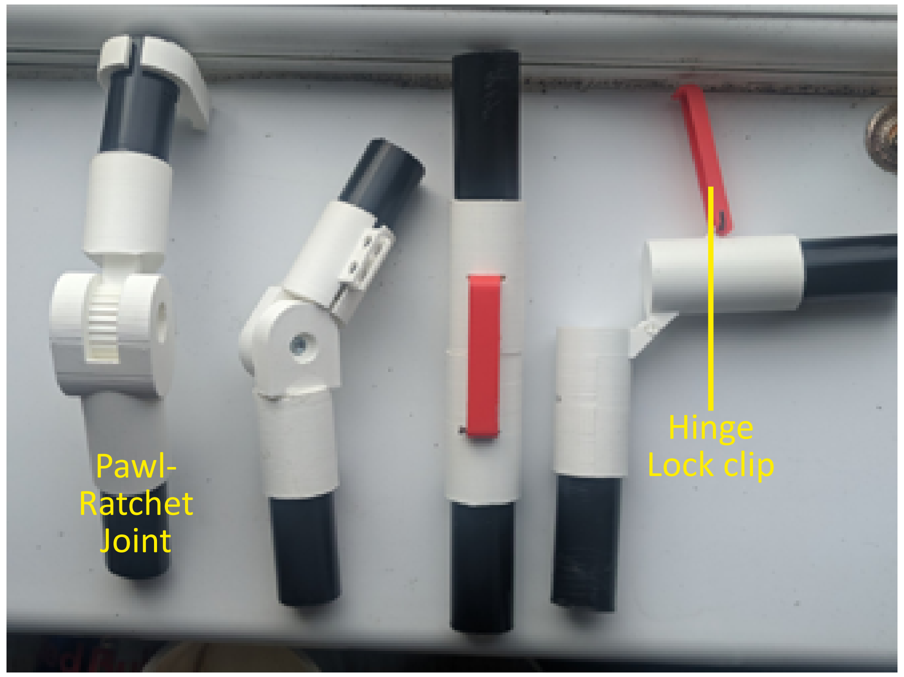
As per suggested by the users and my tutors, the following section includes my second stage prototypes of **a Hinge to connect link of Arm rest and Foot rest, A foot rest iteration and Brake section.**



The above image is visualize the parts i am about to explain about in the next sections.

Iterations for Hinge Mechanism:

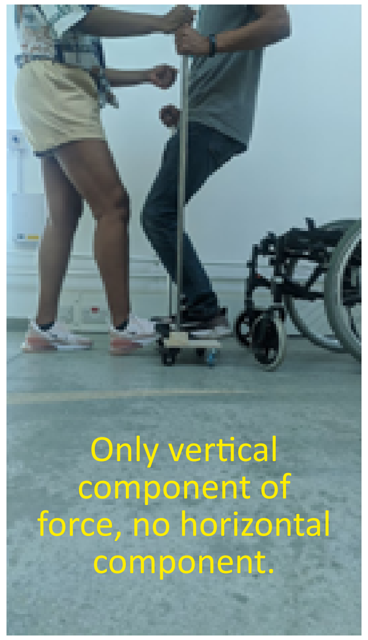
To overcome the questions asked by my tutors regarding the unreliabilitity of the device due to too many joints, besides decreasing the number of links from three to two, i engineered three types of hinge joints.
The first on the left is a Ratchet-Pawl hinge which allows hinge to lock at any position, where as the second one is just a normal Pivot joint.
At this stage of design, the right most joint seemed to be the best option, it locks the joint using a push clip to block it from moving.



Trickiest Engineering Challenge: Footrest Design

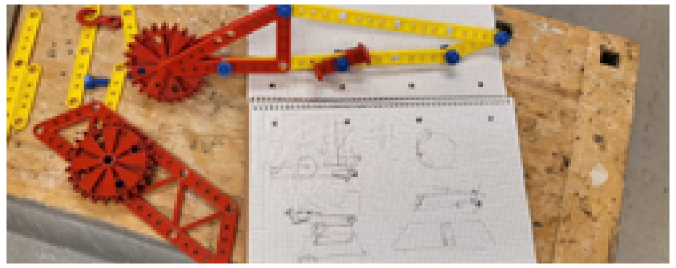
Perhaps the most trickiest engineering of this project was to design a stable footrest which won't move when a patient steps on it, but should be able to smoothly move and rotate while transferring the patient.
A mockup was created to test if the simple castor wheels could solve the above mentioned task, **it failed miserably**!

To make this i used two castor wheels with brakes and two without brakes and attached it at 4 corners. Patient's sside edge would have non braked wheels.
Patient users felt like stepping on a skateboard just to get slipped.
Also, caregiver rejected saying, they feel the joint might fail as there is no horizontal force and only vertical force on the footrest.



Eureka Moment but wasn't used later:

It took almost 45 Days for me and technician Joe Cherrie and Julia Lazzaro, also almost 2 hours on that paticular day to solve the footrest problem!
After a lot of iterations and engineering conceptualizations, me and the fellow technicians developed a footrest concept which can be Wheeled while transfering the patient and unwheeled when patient getting onboarrd.
Mechanism Consisted of a 4 bar link mechanism, pushing a yellow link above would engage the red wheel giving one more wheel to a footrest and allowing it to move.
Looking at the complexity to assemble, i decided to not use this mechanism at the end.



FUNCTIONING

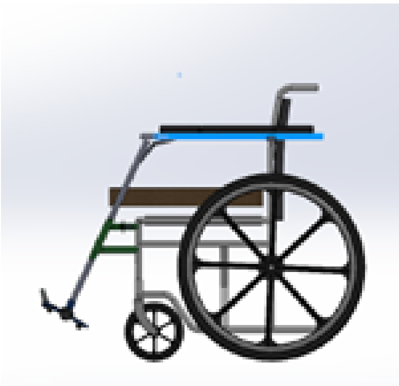
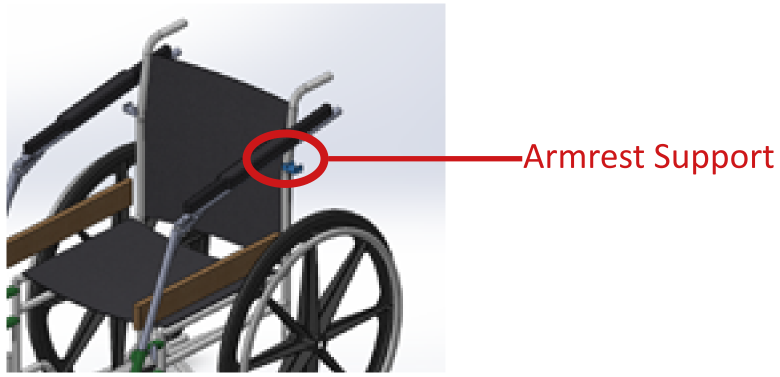
Final Functioning & Design

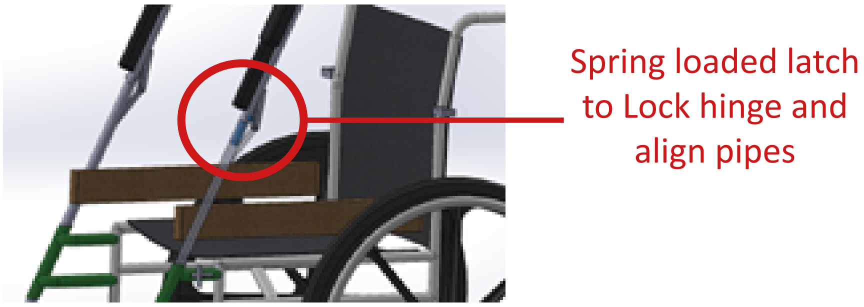


Final Functioning of the product can be explained into following 4 parts:

1. Procedure to unfold the Armrest:

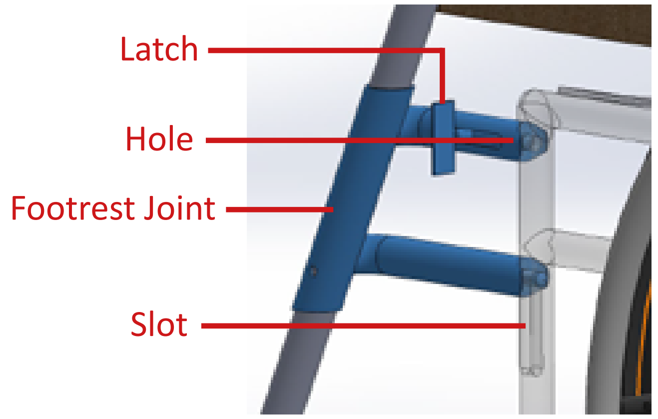
- Armrest hinge can be unfolded by simply lifting up an armrest straight.
- When folded, Armrest sits on a hard plastic support attached on the frame of the wheelchair.
- When unfolded, a spring loaded latch aligns the Armrest pipe with the Footrest pipe.
- Latch not only locks the hinge from folding back again, but also transfer the load to the footrest.
- Spring loaded metal latch can be pushed back up while folding back the armest.

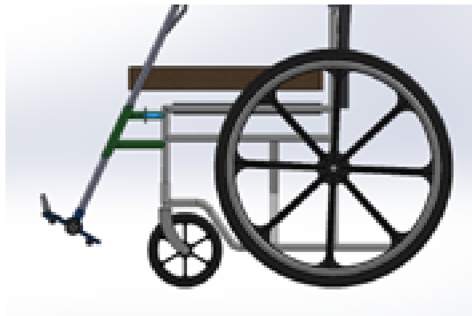



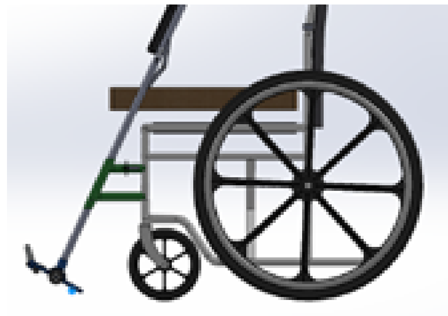



2. Disconnecting the Equipment from the Wheelchair's frame:

- Equipment is attached with the main frame of the wheelchair with a very interesting mechanism.
- Wheelchair frame consists of a hole and a slot.
- Footrest joint can be disconnected from the wheelchair frame by operating a simple latch.
- As soon as the latch opens, the joint slides down the slot and the lower footrest touch the groun.
- Footrest Joint comes out of the slot due to its own weight and can be oput up straight to apply brakes.




Latch operated


Footrest touch the ground


Product can put up straight

3. Applying the brakes for smooth onboarding of the patient

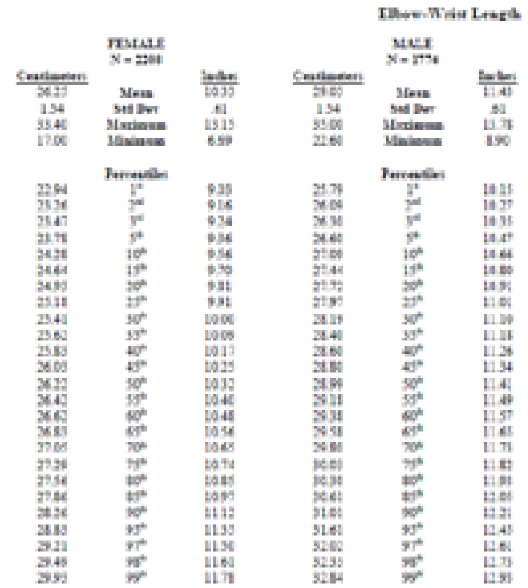
- Once an equipment is detached, brakes can be applied by pusing the lever by simply kicking and the footrest will be fixed on the ground.
- On ground, footrest is supported by a translating, roller wheel and ball rollers on the four edges.


FINAL DESIGN

Design Features

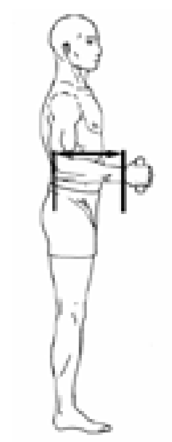
Arm Resting Pads:

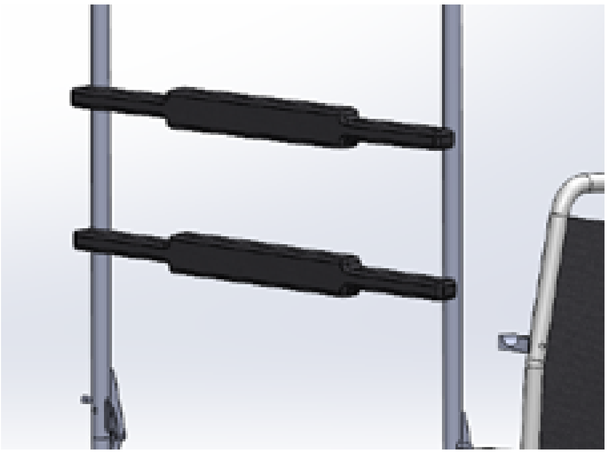
- Arm resting pads were given a special shape for patients to hold on it easily while transfering, without hindering the experience of resting their arm.
- The dimension of arm rest were optimised to be suitable for 95 percentile of people.
- Anthropometry data would be found in the working journal.

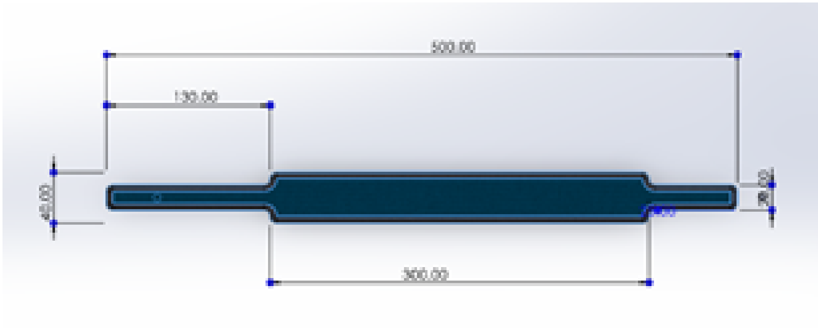


Elbow-Wrist Length

FEMALE N = 2208 Centimeters		Inches	MALE N = 1774 Centimeters		Inches
26.23	Mean	10.33	29.00	Mean	11.43
1.54	Std Dev	.61	1.54	Std Dev	.61
33.40	Maximum	13.15	35.00	Maximum	13.78
17.00	Minimum	6.69	22.60	Minimum	8.90
	Percentiles			Percentiles	
22.94	1st	9.03	25.79	1st	10.15
23.26	2nd	9.16	26.06	2nd	10.27
23.47	3rd	9.24	26.30	3rd	10.35
23.78	5th	9.36	26.60	5th	10.47
24.28	10th	9.56	27.09	10th	10.66
24.64	15th	9.70	27.44	15th	10.80
24.93	20th	9.81	27.72	20th	10.91
25.18	25th	9.91	27.97	25th	11.01
25.41	30th	10.00	28.19	30th	11.10
25.62	35th	10.09	28.40	35th	11.18
25.83	40th	10.17	28.60	40th	11.26
26.03	45th	10.25	28.80	45th	11.34
26.22	50th	10.32	28.99	50th	11.41
26.42	55th	10.40	29.18	55th	11.49
26.62	60th	10.48	29.38	60th	11.57
26.83	65th	10.56	29.58	65th	11.65
27.05	70th	10.65	29.80	70th	11.73
27.28	75th	10.74	30.03	75th	11.82
27.54	80th	10.85	30.30	80th	11.93
27.84	85th	10.97	30.61	85th	12.05
28.24	90th	11.12	31.01	90th	12.21
28.83	95th	11.35	31.61	95th	12.45
29.21	97th	11.50	32.02	97th	12.61
29.49	98th	11.61	32.33	98th	12.73
29.93	99th	11.78	32.84	99th	12.93

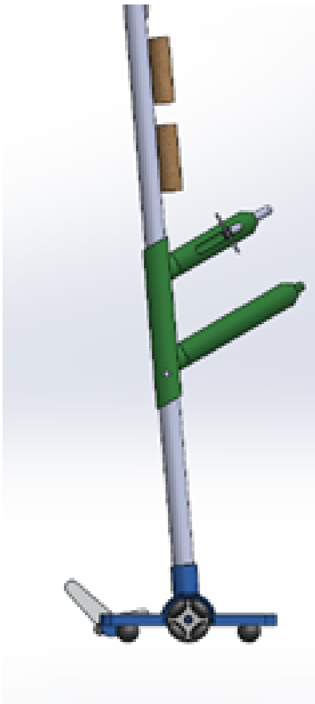


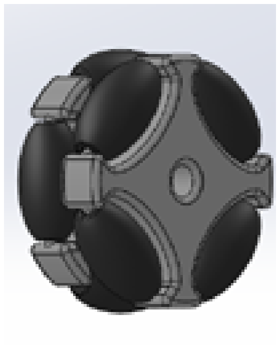




Footrest support:

- Footrest was supported by translating roller wheel and rubber ball castors for smooth translation on roads under the weight of the patients.
- It can be observed that the footrest pipe is not at right angle with the footrest, a light slope ensures that footrest will have a horizontal component of push force when transferring the patient.





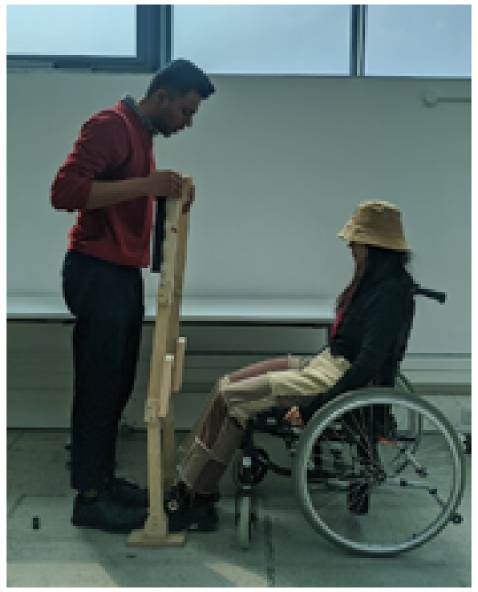
Thigh Guards transform as Knee-Pad:

- Arm resting pads were given a special shape for patients to hold on it easily while transfering, without hindering the experience of resting their arm.
- The dimension of arm rest were optimised to be suitable for 95 percentile of people.
- Anthropometry data would be found in the working journal.

USER JOURNEYS

1. Open the Arm Rest

1.5 Detach the equipment from the wheelchair

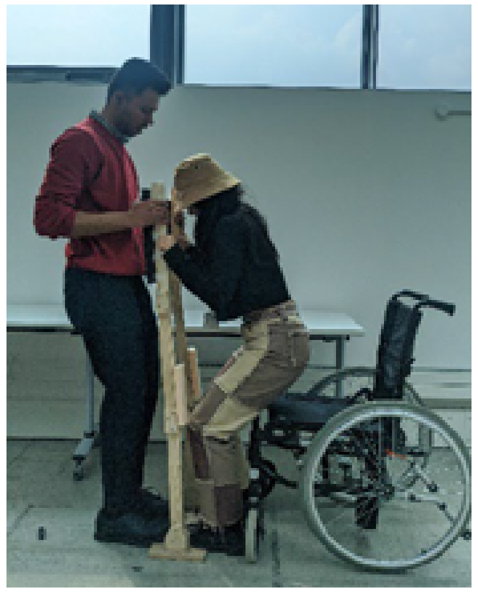


2. Lock the hinge, Arrange the Arm bar and Knee pad

3. Slide the equipment near the patient untill their knee touch the pads

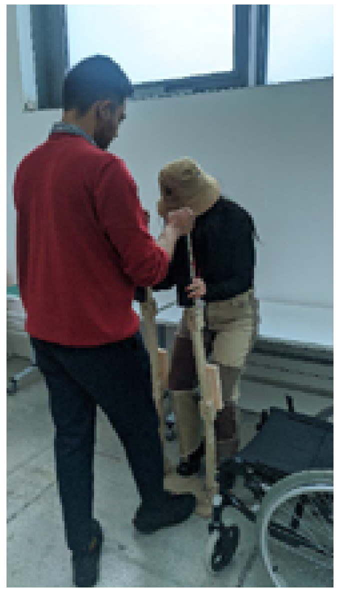
4. Lock the Brakes

5. Ask patient to hold the arm bars



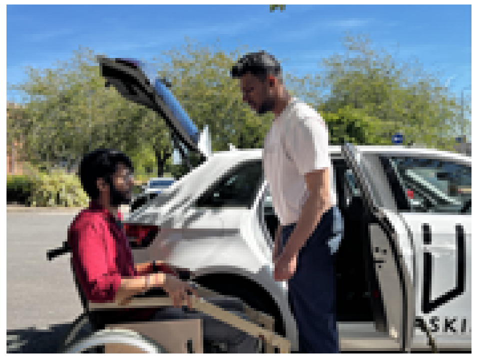
6. Ask the patient to gently stand up holding the Arm bar

7. Rotate the patient towards the Car's seat



8. Slide the equipment towards the seat untill patient can sit

- Both the journeys, shows similair journey of User but in different environments. First Journey shows transferring patient on a bigger SUV type of cars with a higher seat, parked in an indoor parkings. Whereas, second user journey depicts the space contraints due to smaller car, also an additional 9th step of protecting head was necessary in smaller cars parked in an outdoor parkings.



1. Open the Arm Rest

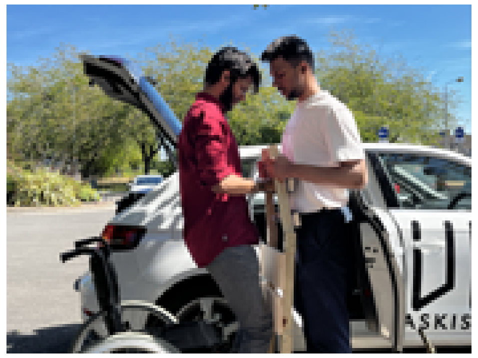
1.5 Detach the equipment from the wheelchair

2. Lock the hinge, Arrange the Arm bar and Knee pad

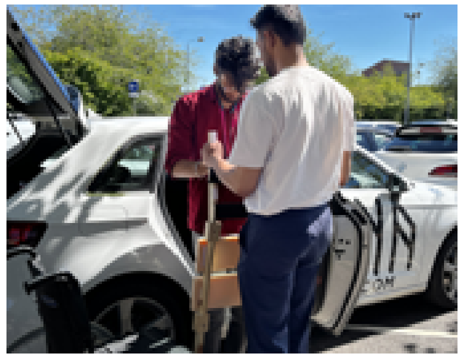
3. Slide the equipment near the patient untill their knee touch the pads

4. Lock the Brakes

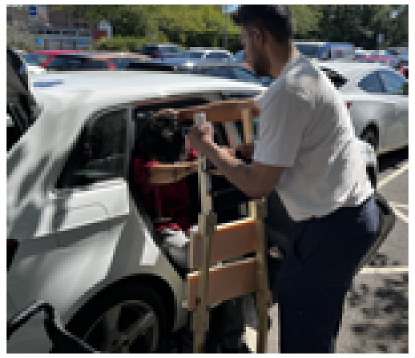
5. Ask patient to hold the arm bars



6. Ask the patient to gently stand up holding the Arm bar



7. Rotate the patient towards the Car's seat



8. Slide the equipment towards the seat untill patient can sit

9. Protect patient's head while sitting

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