Mechanics of Human Movement
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Lecture – 50
Journey of Standing Wheelchair Development

So, I wanted to start off with this, when you look at knee stability the factors that influence it are the load line. How the load line is located with respect to the knee then of course, you have your hip moment that can be used to influence the load line. And of course, the location of the knee center itself; where the knee center is located.

These are three factors that would assuming that the knee by itself does not have some breaking mechanism. If there is some breaking mechanism that moment would also play a part. But assuming there is no breaking system in the knee, the three factors which influence the stability of the knee are the hip moment, the load line and the location of the knee center at that particular instance.

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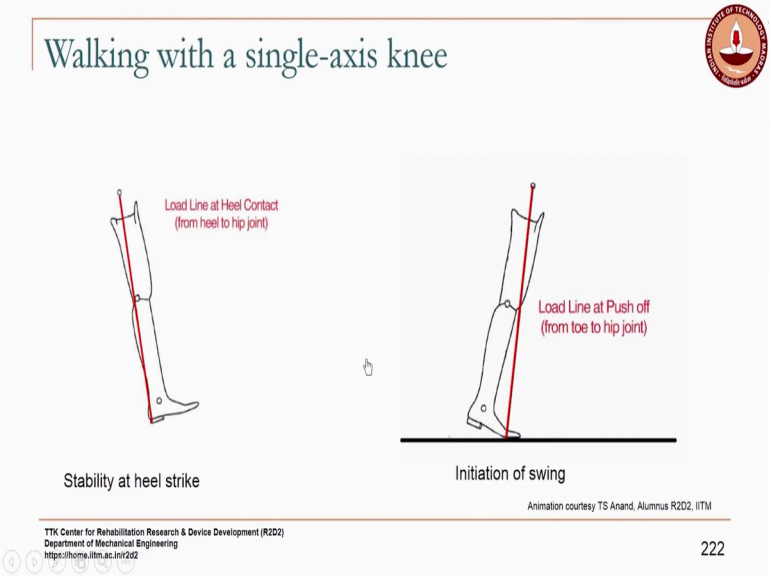

So, this animation we had trouble making it play yesterday, but you can see here for a single access knee.

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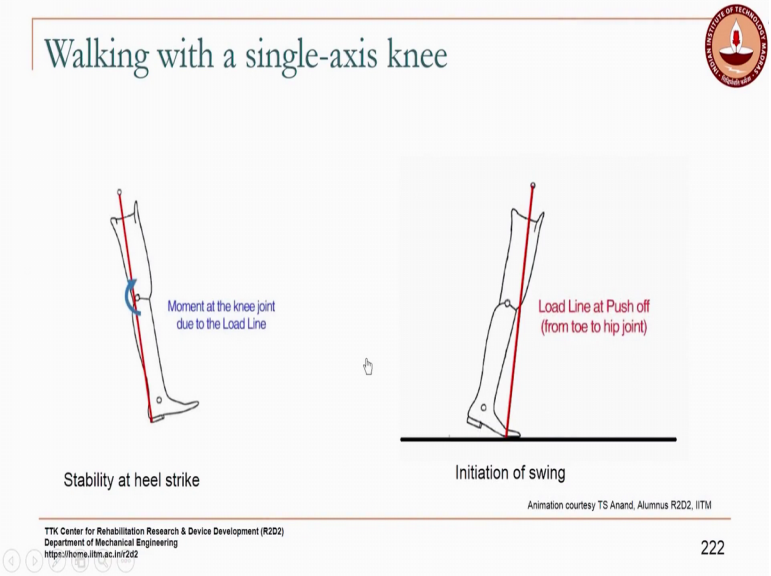

If the load line is behind the knee, then the moment at the knee joint will tend to make it buckle right.

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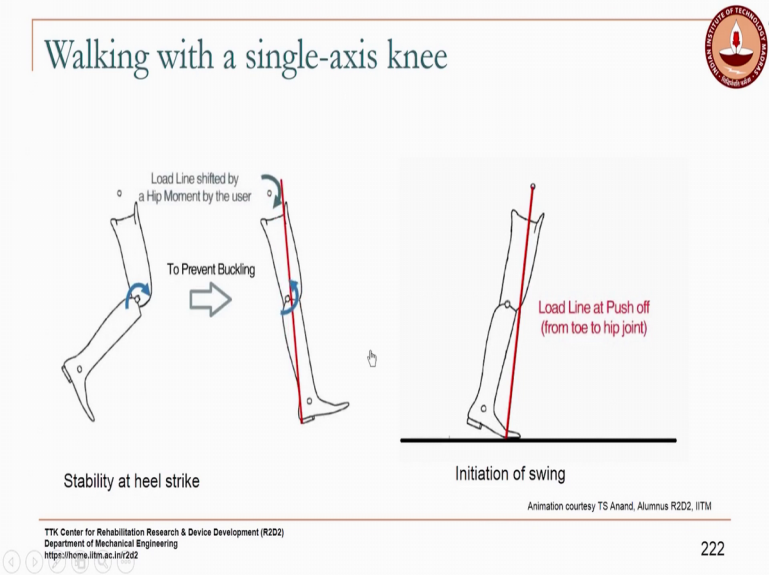

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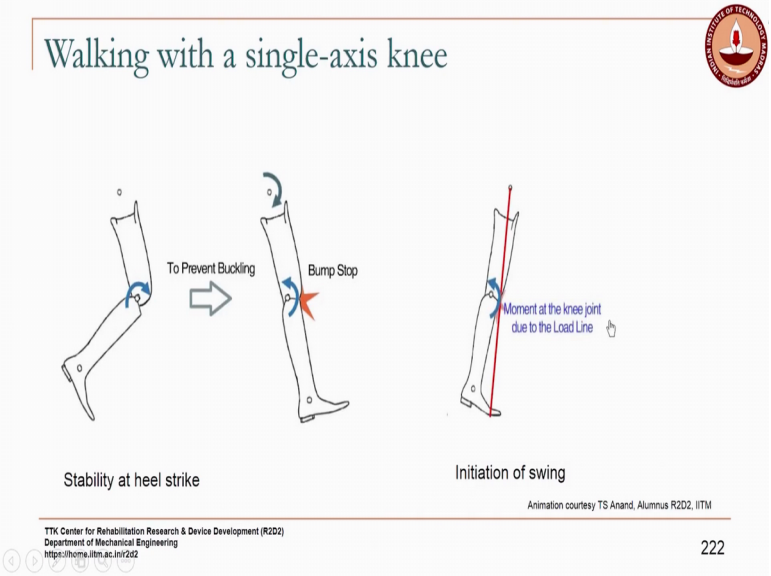

So, to prevent the buckling what the user does is they apply a hip extension moment which causes it to hit the bump stop, which causes the knee to lock by contacting the bump stop. And, that moves thee by moving that load line, it now generates an extension moment about the knee.

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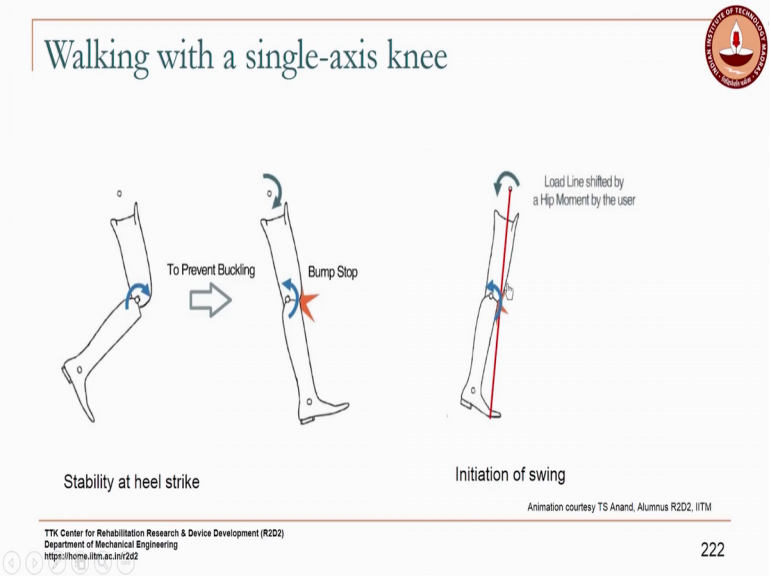

Now, in the case of push off, the moment at the knee joint due to the load line is an extension moment.

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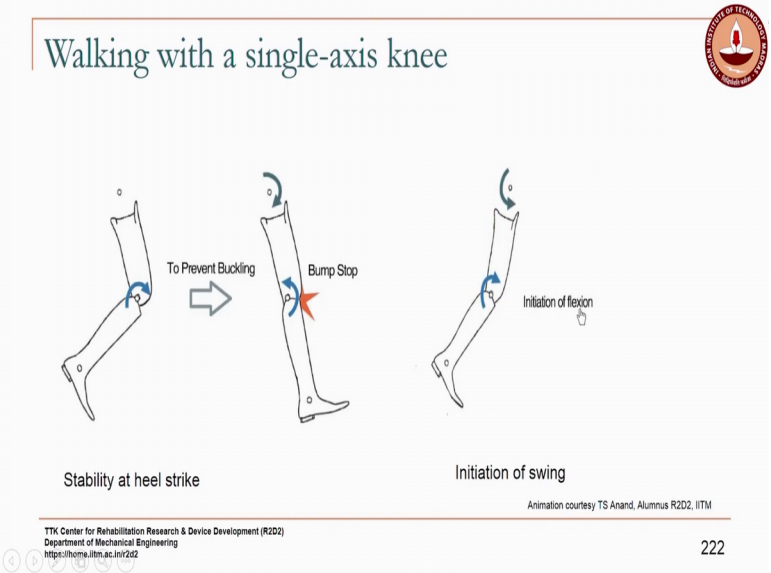

And now so, the user applies a flexion moment to shift the load line and initiate flexion. So, this is the working together of the how the user can use that residual hip moment or that normal hip moment to shift the load line in order to create extension or flexion at the knee in the absence of active control at the knee directly, because you are controlling the knee through the hip here ok. So, I just wanted to show you this animation.

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Moving on we will see so, this is an example of a sophisticated knee which has a microcontroller it is called a C-Leg. It is quite expensive, several tens of thousands of

dollars, I do not know what the current price is, but this is a very sophisticated knee that has a microprocessor on board and it has some sensors. So, there are sensors that detect loading at the foot and ankle, there are sensors that detect the knee angle. So, depending and there is an algorithm which looks at the interrelationship between; so, these quantities to decide you know whether it is a stumbling situation or whether it is a normal situation.

And you know how to regulate the movement of the knee by controlling the hydraulic unit that is in there ok. So, the hydraulic unit it makes so, the controller makes adjustments to the hydraulic unit in order to control the movement of the shin with respect to the thigh. So, this is an so, it has a rechargeable battery it has so, the microprocessor reads with a frequency of 50 hertz 50 times per second it processes this data. So, and then you have loading. So, and then if you want to sort of do other activities there is like a switch and that is by tapping the toe ok.

So, they so, you will have different programs for this knee ok, it will be programmed with different things. So, if they want to bicycle for instance ok, in order for the, they will tap this toe to activate that program. So, it is like a switch ok. So, they have a mechanism to switch programs, say the person wants to do let the knees swing freely as when they are cycling or something like that or if they want to stand for a long time and so, they just want to lock it ok.

They do not want to have to worry about it or think about it; then they can access those different programs by just tapping the toe repeatedly. So, there are so, this is there are other microprocessor controlled knees as well and these knees you know can help a user go down step by step, you know when they are climbing downstairs or climbing upstairs. So, they allow the user a more natural gate, but they are very expensive very expensive.

So, today I just wanted to talk to you about different kind of so, we have talked about assistive devices for walking ok. We have looked at walking in detail and we have talked about an orthotic or a prosthetic limb for walking, but for many people with impairments walking may not be a possibility ok. So, for those people a wheelchair is the may be a preferred mode of transport. It gives them independence, it enables them to move around which they otherwise would not have and move around in a fairly energy efficient manner ok.

So, today I just wanted to talk to you about you know in the development of an assistive device, what does a design journey look like ok. And, we will talk about the development of this standing wheelchair because, one aspect is understanding the user needs and developing a design, but to actually make that design reach the market what are some of the steps involved. So, I thought you I could give you a glimpse into this design journey today.

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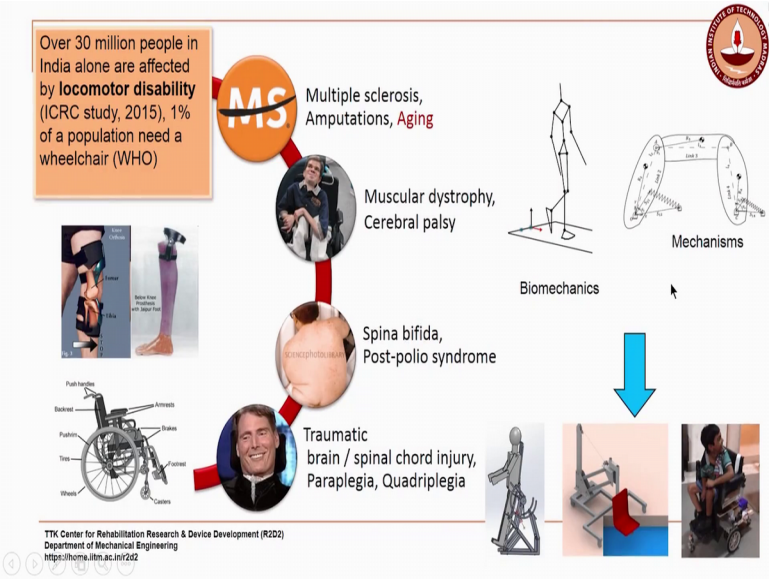

So, if you look at the statistics over 30 million people in India alone are affected by some kind of locomotor disability ok; which means they would need some kind of an orthosis, prosthesis or a wheelchair ok, three broad categories of mobility devices. And, it could be because of various types of impairments, it could be spinal cord injury, you know paralysis, traumatic brain injury, some kinds of genetic disorders, cerebral palsy, muscular dystrophy etcetera. There are various causes and therefore, some of the needs are also going to be different. But, a wheelchair is a mode of transport that is either you know in an assisted manner or self operated manner that can give a person who can otherwise not walk mobility.

Even aging you know many of us once we get past a certain age, it may there may come a point where we may need to use a wheelchair for mobility ok. So, any of these so, an assistive device is not necessarily something that only a specific portion of the population will use. I mean as we as the lifespan is increasing more numbers of us are

going to need assistive devices. In fact, all of us even now use assistive devices. What assistive devices do you is commonly see, your spectacles right it is a compensatory device for better eye functioning. So, but it is become very accepted. So, and it is even become a fashion statement right, people have different glasses that they use when they wear different clothes for instance or for different modes I do not know.

So, I mean people do have multiple you know it has become a fashion statement. So, when you are developing an assistive device you have to keep that in mind. So, when you design an assistive device it is there it is a lot about the functionality, but it is also going it should also be something that a person feels proud to own ok. It should not just be that here is a device and that is it you know, it should be something that you feel happy to own. Not only is it providing you more functionality, but also something that is a matter of right.

So, in the development of assistive devices a lot of engineering knowledge goes in, but along with it there is also a biomechanics knowledge that will go in. Because, most assistive devices there is the human device interaction is very close; you know with the prosthesis or the orthosis you are literally you are wearing it. With a wheelchair you are probably spending many hours sitting on it. And, you know how you interact with the different operations in the wheelchair all those you know how much force can you apply.

What is the correct posture that you can sit in so, that it does not hurt you in the long run or that you do not develop other pain or things like. So, there is a lot of biomechanics knowledge that will go into designing an assistive device as also a lot of engineering knowledge. So, in our lab a lot of what we do is mechanical engineering. So, we do not we have not used we have not designed a lot of devices that require you know microprocessor control or although we will eventually get there. But, right now we focus a lot on mechanical devices for two reasons: one is affordability anytime you go into motors, controllers, batteries the cost significantly goes up.

The other reason is in India power is still a luxury for mean we still experience power cut. So, if you are for a device that is essential for a person's daily life, if the dependence on external power is high then that it is that in itself becomes a disabling factor. So, you want to minimize that dependence on external power. So, a lot of the devices that we develop tend to use muscular effort to accomplish the task.

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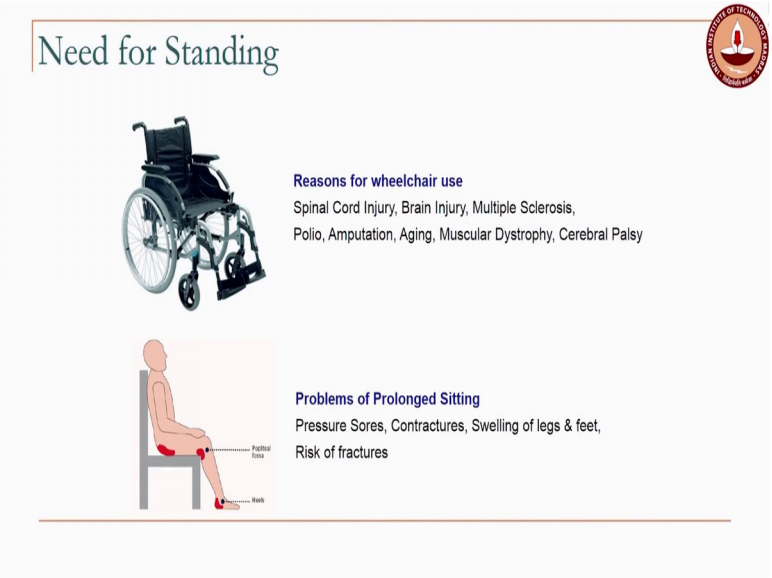

So, now we will look at this. So, wheelchair is for mobility it is you know and there could be like I said various reasons for using it. Spinal cord injury is a big reason for using a wheelchair, polio to some extent yes, if they are not able to use you know if they have used a lockni for too long and it starts hurting they may have to move to a wheelchair, aging of course, etcetera cerebral palsy and all there are also problems. So, while a wheelchair can be a huge enabler for independence the prolonged sitting can also cause various problems in the long run. We all know you know even in sedentary lifestyles today right you are encouraged to get up and walk after every few minutes. You know people say do not keep sitting in one place looking at a screen get up and walk around a little bit right.

So, the reason for that is, if you are sitting for prolonged periods of time and especially if you already have other problems, because of which you are in a wheelchair you are using a wheelchair then you could have issues like pressure sores. So, for instance many people with spinal cord injury lose sensation also. So, they will not know that they are putting too much pressure on a particular area. So, if the posture is not correct or you know if there are some they may not even sense anything that is wrong with the wheelchair; say there is some sharp protrusion or they may not even realize it.

And if there is a pressure sore and it is not detected early it could be a life threatening complication. Just sitting for prolonged periods of time your weight is being it will cause

pressure sores in those area especially, where there are bony prominences because the contractors could develop because you are not exercising the range of motion at those joints right. So, they may get frozen at in certain positions, swelling of legs and feet and because you are not loading your bones in the lower limb slowly the bones start regenerating. With the result that if you happen to fall down, your risk of fracture goes significantly higher because your bones become more brittle ok. So, these are some of the issues with prolonged sitting.

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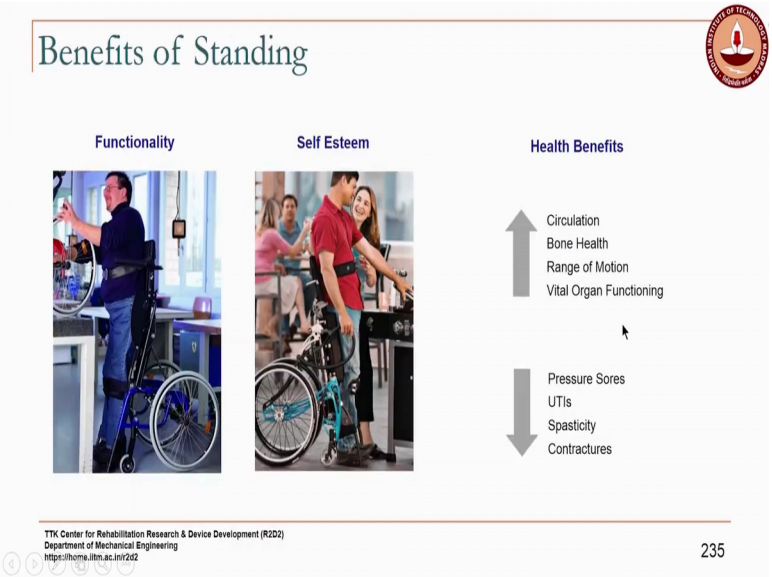

So, a standing program is actually prescribed for many wheelchair users. So, as part of therapy they are supposed to follow a standing program. And, a standing posture really benefits you in multiple ways, one is better functionality yes.

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In activity of muscles the muscles are not. So, the bones are not being loaded yeah, but it is a living structure I have mentioned this before. If the bones the mineral composition changes, if the bones are not loaded then the composition of the bones changes they start becoming more brittle. So, that is why the risk of fractures goes up.

Student: (Refer Time: 16:26).

You are not using the bone.

Student: (Refer Time: 16:30).

It becomes.

Student: (Refer Time: 16:33).

It becomes more ductile, why would you say that?

Student: (Refer Time: 16:41).

Ductile is so, when is fracture immediate. I mean in the sense a ductile material will yield.

Student: Yeah.

Before bone is not like that, the composition is such that it is more likely to crack ok. So, it fractures rather than yielding you do not see bone ok. So, if there is a fall it is going to be a fracture that happens. So, a standing position can provide you better functionality you can access so, in most places if you see switches or shelves will be located at higher levels. So, if you are able to stand or you know if you have a job where you have to work at a table that typically requires a standing posture for you to be able to work effectively. So, functionality is improved if you are able to stand even more than that the psychological well being.

Because, this were you know in many cases so, for instance with people with spinal cord injury they were able to stand, they were able to walk before the injury happened. So, if they are now so, being able to stand or if you are in a room full of people who are standing and you are the only one in a chair in a wheelchair. Then there is there could be issues with self esteem, you feel that everybody is talking down to you. So, being able to stand can also have an effect on your psychological well being.

And, besides this there is a lot of research that shows that there are a lot of health benefits to standing. It improves circulation; it improves the bone health because of the loading. Range of motion at the joints and vital organ functioning also your respiratory system, your excretory system everything work better if you are also able to if you are able to be in the standing posture for some time. And, then it reduces the incidence of

pressure sores, urinary tract infections, spasticity and contractures. So, these are all benefits that that are well known for standing.

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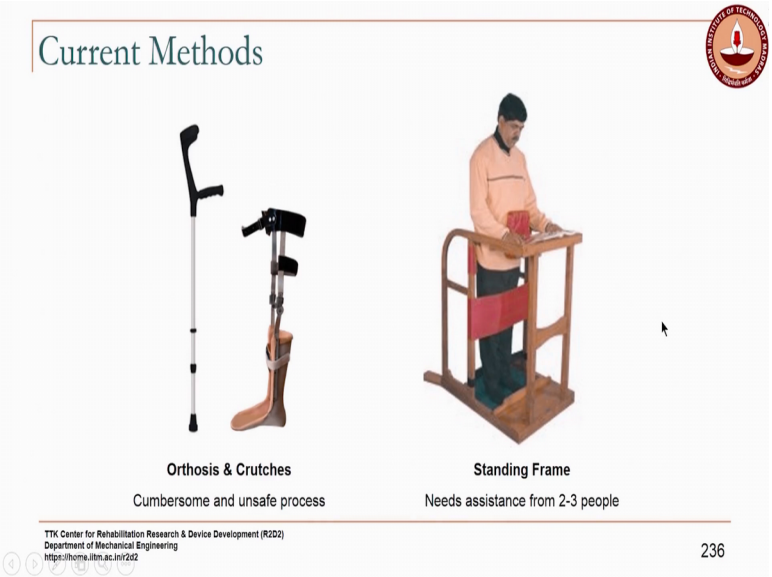

So, a wheelchair user is encouraged to follow a standing therapy on an everyday basis. Most wheelchair users should are encouraged to incorporate some kind of standing in their everyday routine, but it is a very difficult task to perform. You know if you say many of them will then have to wear like an orthosis with a lockni or depending on the level of. So, they may have to wear an orthosis, they may have to use crutches or somebody will have to help lift them out of the wheelchair. And, then they have to stand for say 20 minutes a day, you know or they may be put in something called a standing frame which provides support at the hips and at the knee to make them stand.

But, at least 2 or 3 people will have to lift them out of the wheelchair and help them get into the correct positioning in this. So, it is a very difficult to and other than you know just accomplishing the standing it does not really improve the functionality a whole lot it can be done for therapy. But so, integrating the standing into the wheelchair can provide a lot of benefits in terms of better functionality. And, it is also integrating that action into their everyday life. You know it is like our putting aside time to exercise, you know if you are encouraged to walk for 30 minutes a day putting aside that time.

And then getting on a treadmill or going for a walk versus ok, let me just walk to work or let me keep my, you know path my car far away and walk a little bit extra. Let me climb

stairs, integrating it integrating that exercise into your everyday activities is a more effective way of ensuring that it gets done. Rather than saying put some time aside and go stand for 20 minutes.

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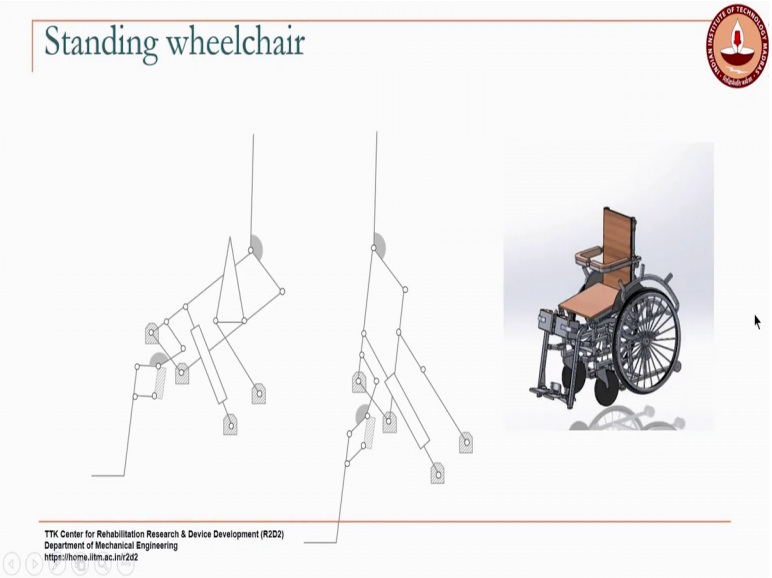

So, that was the thought behind the standing wheelchair. There are some models available in western countries extremely expensive; they cost about 15,000 US dollars ok. So, but if you look at it, it is essentially a mechanism design problem. If you look at the functioning of the standing wheelchair you know it is you have to make that chair come up to a standing position. So, so we started looking at it as it is just an interesting mechanism design problem.

Let us let us see if we can design the mechanism that can get this chair from a sitting to a standing position that is what it started off with; the kinematic design of the mechanism to accomplish this task. So, this journey started about more than 5 years ago ok.

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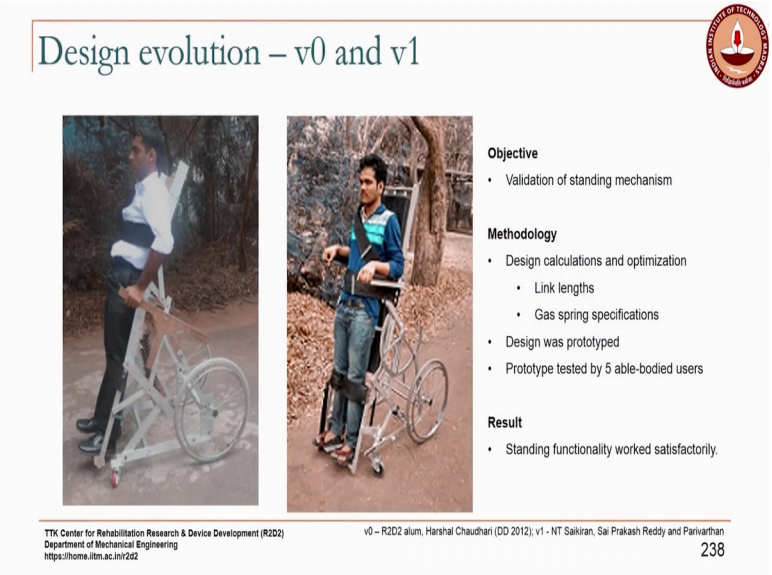

So, and then the very first prototype was built by one of my students former students who did it who did this as his dual degree project ok. So, initially in a in a kinematics course some students had come up with a few different designs, but they did not make a full prototype. Harshal, the first student he took it up as his dual degree project, did all the analysis and he actually built this was his second prototype.

So, the first prototype he had the mechanism designed he knew it was, but when he tried to stand up on it ok; beyond a certain point he could not apply enough torque to lift himself up. Remember a person has to apply torque with their arms enough to lift themselves up to the standing, lift their entire body weight to the standing position. So, it is not an easy task.

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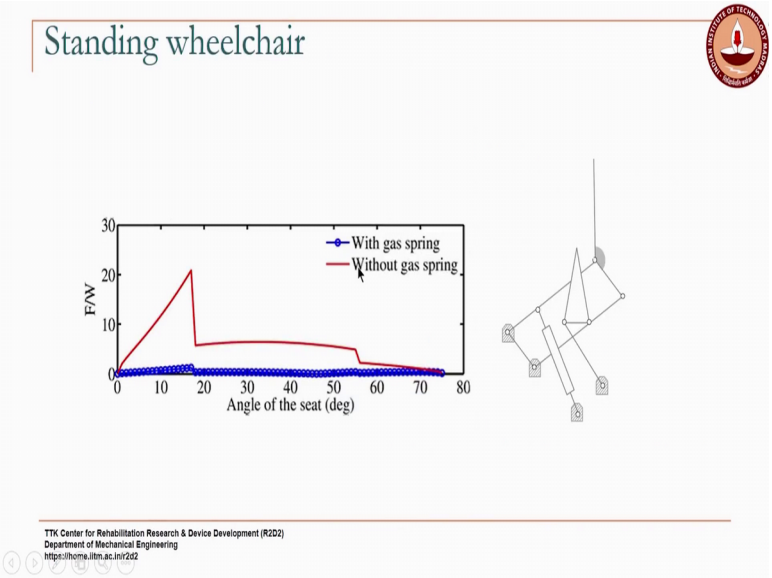

So, then we looked at spring balancing and we realized that without a spring. So, you have a gas spring here or actually Harshal first started off with a regular compression spring, but that spring sort of balances the weight and that enables you to apply a torque that is possible by a human being ok. So, using a spring he built this version 0 and it was made out of wood and aluminum and you know it was really a rickety structure that only he had the courage to stand on. So, that was the first prototype that was built and you can see that he is, the second one then we said we have to make the design more robust ok.

So, we did some more analysis because you know time constraint Harshal left, then next bunch of students they took up they did some more design calculations, did some more optimization. And, using stronger materials fabricated a prototype that could now be used by some able bodied users, some of us could try the prototype. It was sturdy enough to try and it was essentially to validate the standing mechanism. So, and this time we used a gas spring because with the problem with the compression spring is there is no damping.

So, if the standing mechanisms if there is no person in the wheelchair and the standing mechanisms gets actuated it just jumps up like that, that is a huge safety issue. You cannot have a device designed for a human being that behaves like that. Gas springs you know it is there is some damping inherently present. So, we were and they are also well

used in many industrial applications. So, they are more durable. So, this standing functionality was the first thing that we validated.

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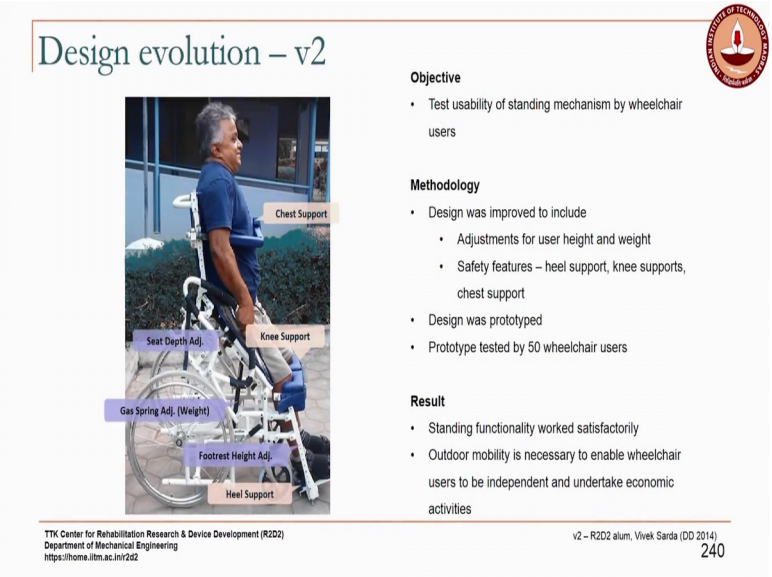

Now, the next thing is the intended user for this wheelchair is not an able bodied user ok. So, when we try to test version 1 with a volunteer, who is actually a wheelchair user we found some interesting things. For instance this person has a spinal cord injury so, as they tried to come up to the standing position their feet kept slipping of the footplate, none of us had experienced that. So, that shows that you know there are so many adjustments and compensations that we make that we are not even aware of, we were all gripping the footplate with our feet without even realizing it. When a person does not have that muscle power to do that that is when you start noticing some of these things.

It starts it started slipping off; the feet started slipping off the foot plates that was one thing. Then of course, for a person with this kind of an impairment it is very you have to have a lot of adjustability. Because, if the standing posture is not correct you know then it could do more damage to them, you know could do more damage than good. So, that is something you have to be very careful about it, again we make adjustments we do not need all the restraints and so, we are able to adjust to an able bodied user is able to adjust to that and still may the mechanism work. But, because the intended user is a person who has an impairment we had to put in more safety features, many of them would not have trunk control suitable trunk control may not be. So, they need to make you need to make

sure they do not fall forward when they are in this standing position, then the knee support is critical.

So, when a person if a person cannot stand it is because, they do not have stability at the knee. So, you have to ensure that that knee is stable. So, the knee support is critical for an actual wheelchair user; so, designing the knee support then the seat depth adjustment. So, that when they get into the standing posture they are not putting undue pressure on the knee, see because these are some of these people have not may not have stood for on a regular basis for a while. So, again you have to be careful that you are not loading places in an abnormal fashion ok.

So, you are not causing more damage. The gas spring so, this is it is to balance the weight of the person different people different weights. So, how do you make the gas spring adjustable so that it can so that you can try this with various users because, these prototypes take a long time to make ok. So, it is not going to happen, you cannot have multiple prototypes to start with for different users ok. And, that is one of the so, when we set out to do this project and we said we would create an affordable device these are some of the things. So, if you look at some of the other standing wheelchairs many of them you it is like a one size; they the bad ones will be like a one size fits all which is not a good strategy for a very diverse population.

The really good ones are custom made. So, they will come if you are a wheelchair user so, we wanted to get one of those devices for benchmarking. They said tell us where, the user is we will come where the user is in the US, we will come take measurements and then build the wheelchair for you. So, it is a custom built device. So, there is huge expense involved if you are making a device of this complexity, if your are making a custom device each time ok. So, our objective so, in making it affordable one is make it mechanical, design it from scratch ok. So, you know you own the IP to the design, but also how do you make it customizable and yet mass manufacturable. For it to be economical, for it to be affordable it has to be mass manufacturable ok.

You cannot be making one part at a time; it has to be mass manufacturable at the same time how do you incorporate all the adjustability that you need to fit a wide range of users. So, these were some of the challenges that were that we dealt with. So, here we found that so, it had safety features it had the heel support you know to prevent the foot

slipping. It had knee supports and the chest support, adjustments for the user height and weight. And, we tested this single prototype with over 50 wheelchair user's different age groups, different height; weight etcetera.

And, to see you know what is standing functionality worked well, each time you have to make adjustments you can adjust the location of the gas springs; so, that the same gas spring can be used for all these people. And, we found that everybody was happy with how this time; the effort required to use the standing functionality was about the same. So, if they could propel the wheelchair then they were able to use the standing functionality, they were able to lift themselves to the standing position. Then we decided at that point because, for this particular project the goal is to get these out especially to the economically disadvantaged users.

Because, they are the ones who lack access to therapy ok, but and many of them we found that when we went on a lot of field visits we found that they are not using even when they are given meals as they are not using it. Because, many of their wheelchairs are unsuitable for use and, use outdoors because of the rough terrain; so, we said we are providing the standing functionality. But, if they are not you know if their houses are too small to use this inside and if what they really need is outdoor mobility, then outdoor mobility is also something that we need to provide in this wheelchair.

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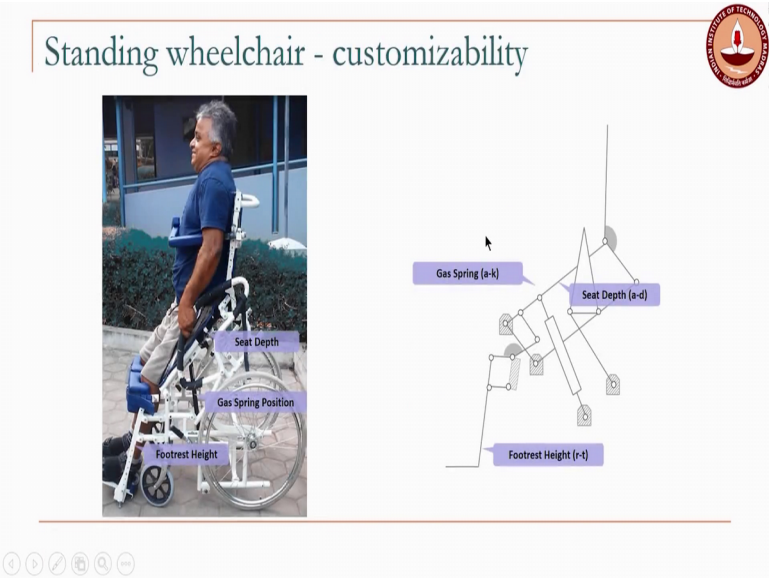

So, here you can see the gas spring you can customize, footrest, height and the seat depth are also.

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So, here is a video of an actual user. So, it functions like a regular self propelled wheelchair.

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And then so, this is a user with spinal cord injury at the T9 level thoracic 9, remember your spinal cord ok, T9 level. And, then you can see they come up to the standing position, it locks in that position there is a and then they can use their own arm power to again come back down ok. So, this was in this version we also hand this linkage to kind of bring the foot rest to the ground. So, that you know it increases the base of support.

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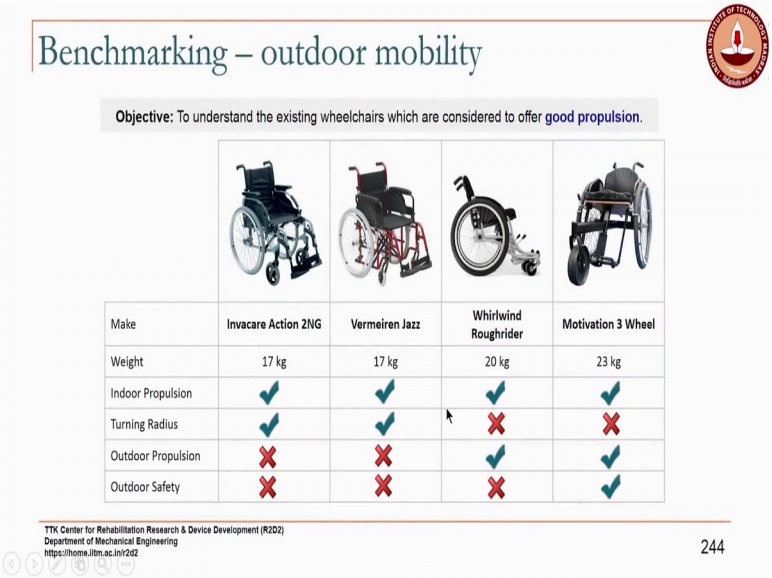

When we realize that we are going to go for an outdoor mobility we looked at existing outdoor wheelchairs none of these have standing functionality, but you know most of

them will have. So, if you look at these regular 4 wheel wheelchairs most of them have a small base of support. For them these are mainly for indoor use, it is for maneuverability, it is for good maneuverability. If you look at an outdoor wheelchairs that will have a longer base of support ok; so, that in outdoors you have better stability.

The really good ones that we found have a 3 wheel configuration. So, they have only 1 caster in the front and 2 wheels and that gives you the tripod support. So, no matter what terrain you are on because, here with the 4 wheels right; if one of the driving wheels gets stuck right it is very difficult to with the 3 wheel support you can navigate uneven terrain better ok.

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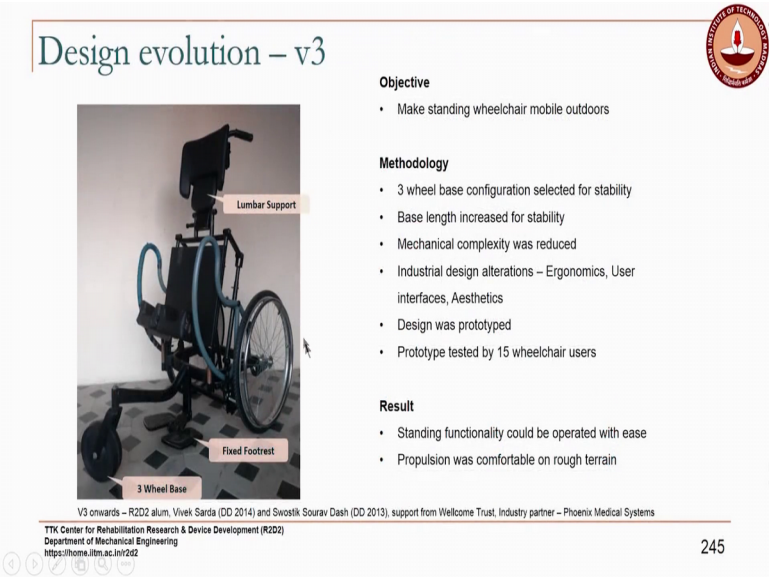

So, we said let us make the standing wheelchair with a 3 wheel base support and that also helped us to eliminate all those linkages to make the footrest move down and contact the ground ok. So, now everything when they are in the standing position they stay within the base of support. Because, if they move outside the base of support your are going to lose stability you do not want the person to topple in the standing position. So, for that so, we went with a device of this nature with a 3 wheel base and with an increased base length ok.

And, a lot of industrial design inputs go into start going into the design because, you know how does the user interact, you know what kind of a handle, how do they hold it, what is a better way. So, a lot of ergonomics goes into seeing how the user interacts, you

know there should not be pinch points. You know where are the likely places where a user's finger could get stuck and how do you eliminate things like that. And so, you know the objective was to make the propulsion comfortable on rough terrain.

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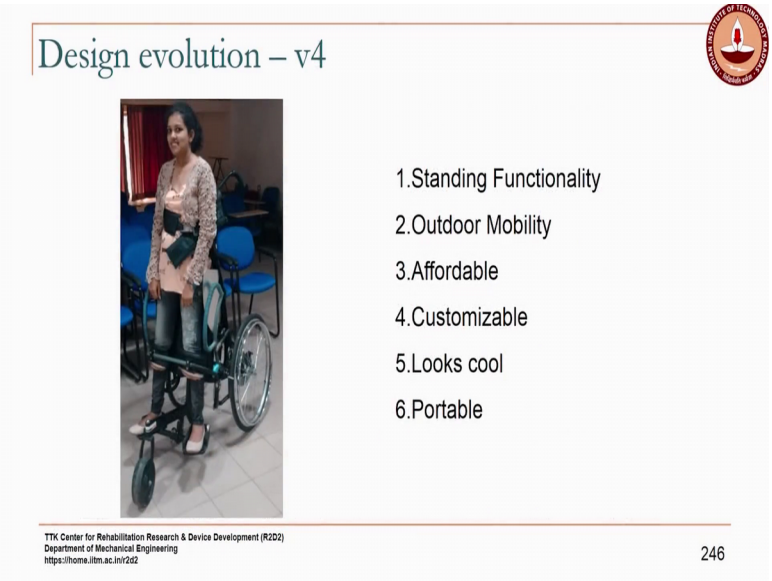

So, you can see as the design evolved the looks started getting better aesthetics started getting better, we also made it portable. So, somebody wants to take this with them on the train or in an auto you know this can these wheels can be removed, the back rest can be folded etcetera. I think right now, I think in the current when the backrest can actually be removed.

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So, this is the evolution you can see from you know a design on paper to version 0 to something that actually looks like a product and it is a long journey, it is a long journey to come there. So, if you look at it we have tested it with both genders, same prototype tested with a wide age group, wide weight range, height 5 feet to 6 feet. So, we are now in the, if you count from the time Harshal started working on it, we are in our sixth year. But, the major development has happened in the last this is the fourth year of major development. So, there was a lull for about 2 years because, one student leaves you nobody everybody wants a new project. The fun is in for most people, the fun is in seeing the first prototype work, because this is a lot of grunt work that goes into making a prototype into a viable product.

You know you have to look at manufacturability, you have to look at a lot of details, it is a lot of it is a lot of grunt work. It is a lot of grunt work whereas; the first part is the most exciting thing. You even that animation you just see that and you are like wow, you know it looks I am done yeah that is that is. So, it really takes a lot of dedication for people to make this journey to be even willing to make this journey from prototype to product. And, especially in an academic setting it is even harder because you know you want people who will stick around and do things like that. I have been fortunate because a lot of my former students have stayed back, they have turned down jobs to stay back and work to make things into products.

So, that is the, and this particular version will probably be more used in the rural areas because of the because this outdoor version is a little difficult to maneuver indoor. But, our next step will be to also create an indoor version for urban uses, for the mandate for this project was to reach as many people as possible with this kind of a design. So, this project is funded by a UK foundation called the Welcome Trust.

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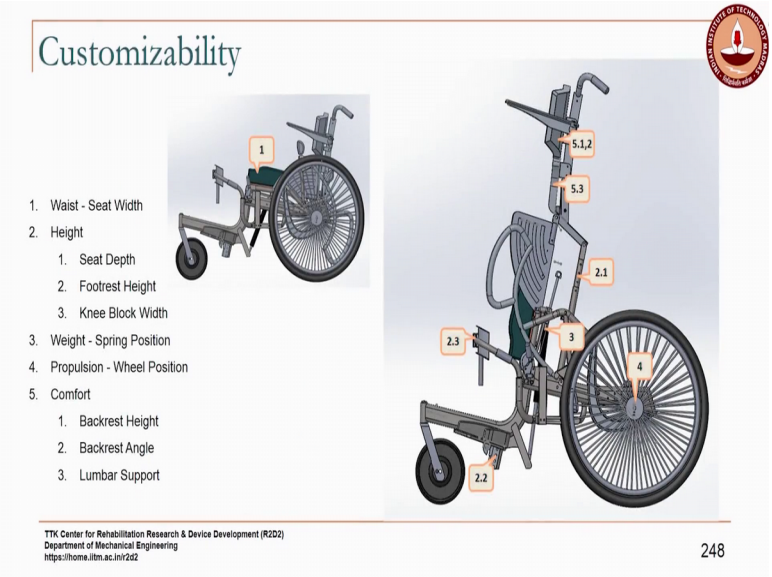

So, these are all some of the customizability that spread. So, seat width so, now, most wheelchairs come in multiple widths to accommodate people of different sizes. So, you know we had to then look at ok, what are the parts that will remain the same through all the wheelchairs. What are the parts that need to be changed depending on the size of the wheelchair? So, a lot of the manufacturing aspects also come into this ok. Then you know other adjustments; height, seed depth, the footrest height, knee block all these have to be made. It has to be properly fitted to the person the first time they come, to balance the weight of the person because the effort you have to optimize it.

So, that it is fairly easy to get up and to get down, if it is too easy to get that get up if it is too easy to come to the vertical position or near vertical position, you do not go give them a fully vertical position because of stability. One they may not have the trunk control and two you want to keep it within the base. So, if it is too easy to come up, then you have to work against that same spring to go down. So, they effort to go down becomes so, there is a lot of analysis also that has gone into this design. So, you look at

the forces in the mechanism you look at you know with the user sitting there what kind of torques are required to go up, to go down and then how do you fine tune ok.

So, for each person there' will be a sweet spot, where the effort to go up and to go down are about the same ok, then they feel comfortable with that; if the effort to go down is if they go down easily then coming up becomes difficult for them. So, you have to find that sweet spot optimize it for each user. Then propulsion, for propulsion the wheel position should be adjustable because different people like to have that in different places to be able to propel easily; again that has to do with ergonomics loading you can do. So, there is a lot of biomechanical analysis that and there are you know for those of you who have gone through this course. And, who may be interested we want to look at for instance we have instruments that can measure the metabolic cost by measuring the volume of oxygen consumed.

So, we want to do some tests propulsion tests with this field sir and some other comparable wheelchairs to measure that data. There is a lot of biomechanical data collection we want to look at the kinematics, when a person how is that when the person is interacting with the wheelchair. You know you have all done projects related to the motion analysis. Now, we want to do the same thing for this wheelchair look at the action as the person is going up coming down. So, you can now do an inverse dynamic analysis compute the loads at the elbow and shoulder etcetera. So, there is a lot of biomechanical analysis we want to look at the interface pressures. The pressure at the knee block we want to make sure it is the values are tolerable at tolerable levels. They will not cause skin degeneration, the pressure should not be such that they will do damage to the skin.

So, there is a lot of biomechanical analysis that still needs to be done a lot of what we have done is it is been tested with over 150 users. So, all the user testing has kind of helped to refine the design as we went along to bring it to the stage it is in now and we expect that this will come to the market maybe later this year that is the goal. So, if you look at; then for the comfort for the user the backrest height you know where they get their lumbar support those things can be adjusted, the angle of the backrest can be adjusted etcetera. So, this all this customized ability is built in to the wheelchair so, that its fit you know there will be a fitting done for a person when they get this wheelchair.

And, after that they really do not have to you know worry about it too much unless something you know their weight changes drastically or something like that.

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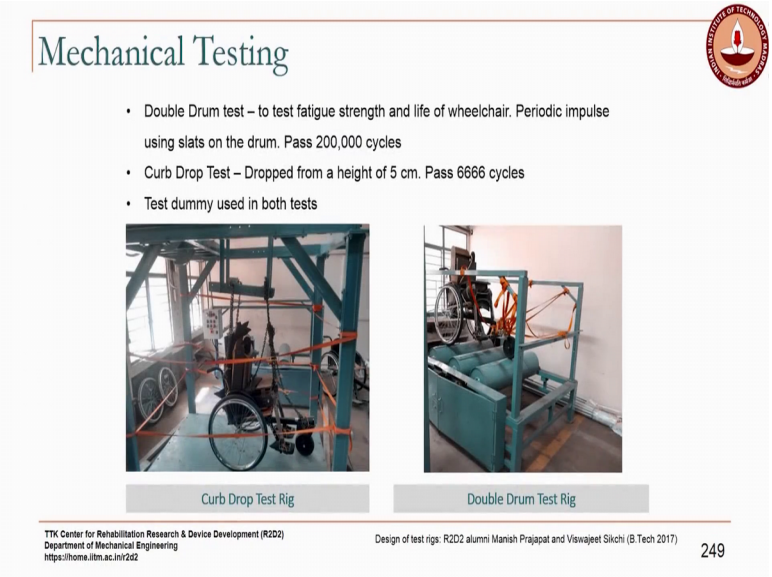

To test the durability of the wheelchairs so, quality is another thing right. We want to make sure that we build a device that meets international standards for quality. So, there are some ISO tests and these test rigs were also designed to execute those ISO tests. There is a test called a double drum test, where you have two rollers which make these wheelchairs move and they also have like slacks in them. So, that there is a periodic impulse that is given to the wheelchair. Just as like you are you are on uneven terrain you know you hit a bump right, small bump that is sort of to simulate that.

And so, the wheelchair is run on this test it has to pass 2,00,000 cycles of this test. Then after it completes the test that same wheelchair also has to be loaded on what is called a curb drop test that is from the curb for the footpath. If the wheelchair you know drops down that 5 centimeter ok, how many of those can it withstand and the minimum requirement is about 6666 cycles. So, this is for the life of the wheelchair and all these tests are done with like a 100 kg test dummy placed on the wheelchair. It is not just the wheelchair alone; it is like with the 100 kg user sitting on the wheelchair. So, you have an actual dummy test dummy those of you who are interested can see in the lab; then can see these tests running. I think we have something going on right now ok.

So, these have to be done, these have to be done for all the different sizes all that; then only then we can go for the long term field testing, where the user will use it in their everyday life for about a month or two. And, then we will feel confident that this product is ready to go out in the market ok. So, it is a long tedious, detail oriented process. There are a lot of steps involved. I have omitted them I have omitted many of them, because there is a lot of detail you know there is a lot. So, before we did this when we actually did the design we did a lot of FEA: Finite Element Analysis because this is an expensive and also time consuming way of testing ok.

Putting something saying if it breaks then going back and fixing it, now this is the last step when you are fairly sure this is to ensure that it will pass. Because, you have to get these products certified, quality certifications require that you have to actually perform these tests. And, because the materials that you get or say in FEA when you put in values for things you are putting in estimates right and you do that to design that. But, in actuality a weld for instance in solid works I can make a perfect weld, in real life a weld may not be that perfect. So, those are things that you can detect when you actually test the parts.

So, if something is not right you know; that means, there is some in the process can we improve the process so, that we get weld quality. For instance these fixtures were also designed by students from our lab two B.Tech students did it as their honours project.

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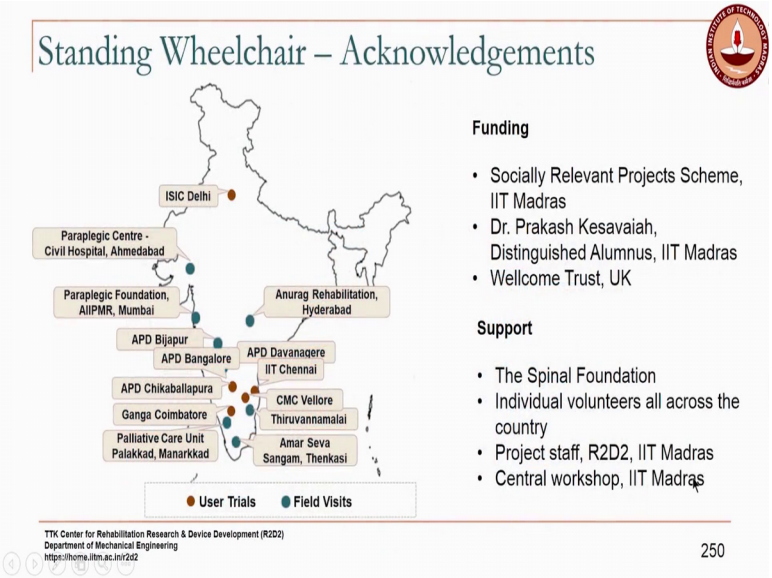

So, I like to close with you know we have done testing of this device at so, many different places, so many rehabilitation centers so, many NGOs that work with people with disability. So, many volunteers all across the country have helped us with testing this wheelchair so far and of course, funding at very critical part of product development. The majority of the funding has come from the Welcome Trust and we hope to finish this project this year and commercialize this design.

The Spinal Foundation is again a user group of people with the spinal cord injury and they have they have been really helpful and giving us you know contacts all over the country to test these devices. So, that I just wanted to sort of close out this course by showing you what a design journey looks like for an assistive device ok. So, as I said it is a marriage of biomechanics and design and a lot of grunt work. So, thank you.

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So, these are some of the other devices those of you who are interested can look at our web page, now this is the device. So, you can see that most wheelchairs are indoor devices, outdoors you need the longer base and the tricycle kind of a device is better to maneuver outdoors. So, this basically converts it into an outdoor device ok. This is a mechanical version; we also have a motorized version of this device. So, this is just to give you a flavor for the different types of assistive devices that are there and what it takes to design a single device.

Thank you.