Wheelchair Mobility: Ultralight Configuration And Propulsion

Recorded August 13, 2019

Presenter: Michelle Lange, OTR, ABDA, ATP/SMS

OccupationalTherapy.com Course #4385

- [Presenter] I am very honored to introduce today's speaker, Michelle Lange, joining us today to speak on Wheelchair Mobility: Ultralight Configuration and Propulsion. Michelle is an occupational therapist with over 30 years of experience and has been in private practice, Access to Independence, for over 10 years. She is a well-respected lecturer, both nationally and internationally, and has authored numerous texts, chapters, and articles. She is the co-editor of Seating and Wheeled Mobility: A Clinical Resource Guide, editor of Fundamentals in Assistive Technology 4th Edition, NRRTS continuing education curriculum coordinator, and clinical editor of NRRTS Directions magazine. Michelle is a res, and a fellow, and a member of the Clinician Task Force. She is a certified ATP, certified SMS, and is a senior disability analyst of the ABDA. Welcome, Michelle, and thank you so much for joining us today.

- [Michelle] Thank you very much. And thank you to everyone for taking time to attend this course. I do hope that it's helpful to you as well as helpful to the clients whom you serve. Today we're going to be talking about wheelchair mobility, specifically ultralight wheelchairs. This is one type of manual wheelchair. We're going to get into some details about how these can be configured and how we can best instruct users on how to propel them in order to increase efficiency and decrease risk of injury and pain. We have learning outcomes for this CEU-approved course. The participant will be able to, one, define an ultralight manual wheelchair, 2, describe ultralight configuration considerations, and three, define the most efficient self-propulsion technique. This is what we're going to be covering in this particular course here today. We're going to define an ultralight manual wheelchair in context of other wheelchair frame options. We're then going to discuss clinical guidelines for the use of ultralight manual wheelchairs. Who are these appropriate for? How are they configured to best meet an individual's needs? And, again, what are our most efficient and optimal propulsion techniques? Finally, we'll finish up with a detailed case study. And that will help hopefully put all of this into context and better prepare you for an examination. Because some of you may be preparing for the SMS examination. So this particular course here is part of a series of webinars and is designed to prepare you for the Seating and Mobility Specialist examination. This is a certification that's available through RESNA. RESNA is the Rehabilitation Engineering and Assistive Technology Society of North America. They have two certifications, the ATP, or assistive technology professional, as well as the SMS. Whether or not this is a certification that you are interested in, I certainly hope that this series will help you to develop more advanced seating and mobility skills.

Let's talk for a minute about manual wheelchairs. A manual wheelchair as opposed to a power wheelchair generally is lighter and generally is designed for self-propulsion, though some of these are more designed for self-propulsion than others. And some are absolutely designed more for dependent mobility for somebody else to push the base, such as a caregiver. A manual wheelchair is designed to provide either dependent or independent mobility to a client, as well as support an appropriate seating system. These chairs can support quite a wide variety of seating systems and a variety of size clients. Now, when assessing a client for a manual wheelchair that assessment is typically done with the wheelchair supplier. The supplier is somebody who participates in the eval, generally is very familiar with equipment options, will submit all the necessary paperwork including certain documentation that you you will be requested to provide, and then, hopefully, will achieve funding approval for the recommended equipment. Once the funding is achieved through whatever the funding source is, a third-party payer, then the equipment arrives. It's ordered and fitted to the client. So we have this entire process of which the supplier is a very critical player.

Now, lightweight, ultra lightweight, and pediatric manual chairs specifically are considered under the umbrella of complex rehab equipment. Complex rehab equipment is typically recommended by a professional who is certified. And with the supplier, the supplier generally will have a certification called the ATP, Assistive Technology Professional. Medicare in particular and some other funding sources actually requires that if complex rehab is being recommended that the supplier has to have their ATP or they're not allowed to participate in the process. So there's many equipment suppliers out there who specialize in complex rehab. Always keep in mind, again, that if you're looking at a manual chair in one of these categories you need to be working with an ATP. Now, a clinician can have their ATP as well. The supplier still needs to have that ATP. Now, when we are assessing someone to determine the optimal manual mobility base for them there's a number of needs that we need to keep in mind. We have to examine and assess the client's available strength, for example, for self-propulsion, even for transfers. The range of motion, muscle tone, and orthopedic status, that's going to impact their required seating needs. And depending on the seating system required that could impact the wheelchair frame configuration.

So if this client has to sit at a particular angle at the hips, or the knees, or even the ankles, we may have to consider a very specific frame for that purpose. We need to assess cardiopulmonary status and fatigue or try to get that information from the medical team. Because part of our assessment when looking at a chair that could be self-propelled is whether this client is able to safely self-propel it. What endurance fatigue issues are we considering? We may choose an ultralight manual wheelchair over say a lightweight manual chair in order to decrease the energy expenditure of the client. We need to keep in mind potential for change in function or size. If this person has a progressive condition that can impact the future requirements of what we're recommending today. We certainly have to keep that at mind. And if this is a person who's growing or is otherwise perhaps gaining weight, that happens to all of us a little more than we want to, we need to make sure that the chair can accommodate this. Of course, we need to look at positioning needs. That's going to determine the type of seating system that's gonna be within the frame. And then environmental needs, where is this person going to be using this manual wheelchair? Is it primarily indoors on level smooth surfaces? Does this family have thick carpeting in the house? Is the client gonna be outdoors? Is it a rural area, are there mostly pristine sidewalks with built-in ramps at each corner? What are we looking at, so we are choosing the best frame? Now, manual wheelchair types, these codes and these terms are really driven by Medicare.

Now, that's not my favorite way of categorizing equipment. But funding is a big driver in these issues. So we really do need to use, most people working in manual chairs do refer to these Medicare guidelines. We have a variety of manual wheelchair types. Let's take a quick peak. We first have standard wheelchairs, K0001. These are not great wheelchairs for practical usage. They tend to be very heavy with very few frame adjustments. These are sometimes referred to as a fleet wheelchair and maybe are the wheelchairs you see when you first walk into a hospital that are kind of parked to the side. So if somebody quickly needed a ride to and from their car into the doctor's office you could use something like this. They're rather indestructible, but certainly aren't going to provide the support that a client needs and are very difficult to push because of the configuration as well as the weight.

We then have a standard hemi wheelchair, or a K2. Even though we have all these zeros in here sometimes people kinda skip over the zeroes and just say K2, K4, K5, et cetera. K2 whenever we see hemi wheelchair, that just simply means that it can be lowered down. Sometimes, if someone is a quote, hemi, usually meaning that this person has had a stroke and has hemiplegia on one side of their body, that person may push with only one hand on their unaffected side, and may supplement that pushing by using the foot on the unaffected side as well. Well, for the feet to reach the floor for self-propulsion we need a lower seat to floor height, and that's this hemi wheelchair. We then have two different categories of lightweight chairs. And there's some subtle differences there that Medicare uses to discriminate those. Then, finally, what we're gonna talk about today, what we're gonna really focus on, and that is custom lightweight and ultra lightweight wheelchairs, K5s. These weigh much less than the other chairs, even less than the lightweight, and have many configuration options that are designed to increase the efficiency of self-propulsion. Other categories of manual wheelchairs also include pediatric, bariatric, and various specialty manual wheelchairs. This for example may include a sports chair, like one designed for tennis. But, again, in this course today we're gonna focus on these K5s, custom lightweight and ultra lightweight. And, again, even though this title includes custom lightweight pretty much most people are gonna think of a K5 as an ultralight chair. Either ultralight, ultra lightweight, same type of chair. In this category of ultra lightweights are chairs that weigh less than 30 pounds. And some of these are as low as 17 to 18 pounds, so very, very lightweight. This is an advantage because the lighter the chair is the easier it is to propel. Perhaps, some of you like to ride bikes.

Well, I have to admit one of the bikes in my garage is a pretty cheap Huffy bike that I bought at Walmart. And it wasn't very expensive, but it's kinda clunky, it's pretty heavy. So I can ride it, and it's okay. But one day I had a chance to hop on my friend's very lightweight bike and thought, wow, I could ride this thing all day long. It's similar with wheelchairs. If you have a clunky heavy base it's more difficult to propel, so that's the point here. These are weighed in different fashions depending on the manufacturer, so it's important when you're reading the literature to know what they mean by weighing a certain amount. It's not uncommon for a manufacturer to say our frame weighs, say, 22 pounds. But if you read the fine print that's usually without the rear wheels, these have been removed. And if there's removable swing away footrest hangers these have often been removed as well, and without an seating. So it's important that we compare apples to apples. If one manufacturer lists the weight of their chair with rear wheels and another without we need to keep in mind that when we're comparing them. And we certainly can ask the manufacturer what's the weight in comparison to your competition if we have similar components mounted. Ultralights also have quite a bit of options available on them, the greatest degree of any of our manual wheelchair categories. So these are available in a wide range of sizes from very, very small pediatric ultralight chairs through an ultralight that can accommodate a very tall adult. There's quite a bit of frame adjustments. These frame adjustments are important for a number of reasons that we'll go into within this course. But they include things like accommodating the seated angles of the client, accommodating a certain amount of growth, increasing the center of gravity and stability of the chair, and optimizing self-propulsion. Many of these ultralight chairs also include suspension. And this is important because as you are self-propelling a manual chair there's a certain amount of vibration that comes through the frame. And depending on the terrain that you are propelling over there can be jars and jolts through that ride that, again, are translated through the frame to the client's body. And that can lead to fatigue, and pain, and perhaps limit this person's ability to use the chair throughout the day. So as a result suspension becomes very important.

There's a variety of front caster sizes, we'll talk about this. In general, the smaller the caster the more maneuverable the chair. But the smaller the caster the more difficult it is to use if you're not on a smooth level surface. These small wheels can get caught even in a crack in the sidewalk. In general, these are designed completely around the fact that we are optimizing self-propulsion efficiency and reducing risk of repetitive stress injuries, that RSI that occurs when people push a manual chair for years, and years, and years. So, who's appropriate for a custom lightweight or ultra lightweight chair? Basically, any client who is self-propelling using both of their arms for a significant time period can benefit from a ultralight manual wheelchair because it's designed to minimize that risk of RSI and to optimize propulsion. And for anyone who's propelling for a significant amount of time and needs to perhaps self-propel for a lifetime we really need to keep this in mind. There's a lot of folks out there who have propelled for decades and destroyed their shoulders, elbows, wrists, and now have to use a power wheelchair as a result. We don't want that to happen. We need to do everything we can to minimize that risk. An ultralight manual chair versus a more standard wheelchair has improved push speeds. So for every stroke I have against that wheel I go further and faster, so we have improved distance and improved pushed speeds than I would in a standard wheelchair. In addition to that, I also have decreased energy expenditure. So I push on that wheel in a standard chair. It costs me a certain amount of energy. I only go a certain amount of distance and only a certain speed. When I have an ultralight I go further, faster, and with less energy. Fortunately, we have quite a bit of research out there. This is a older study, but a very good one that shows just this, there's been a lot of research about this that has impacted ultralight wheelchair design.

When I'm looking at options for a client with the ultralight category of manual chairs these chairs tend to fall into two major categories, folding and rigid. Where when we look at other categories of chairs, certainly standard and most of the lightweight, these are only available in folding. So, why do we have these rigid frames, and what does that mean? Well, a typical wheelchair that most people think about folds from side to side. And we'll see a picture of that in a moment. Instead, a rigid chair the back folds down, and the wheels can be removed. Rigid frames are lighter than folding chairs because we don't need the technology, the additional hardware that's required to allow this to fold. They tend to be more durable, less moving parts, and more energy-efficient. When the client is pushing this some of the energy is not lost in the folding mechanism. Instead, it moves the chair only forward. But a folding chair can be easier to transport, and often has more growth or other frame options. It also is easier sometimes for certain types of transfers like a stand pivot transfer because those footplates swing out away, as opposed to a more rigid option.

Again, rigid frames are more efficient to propel than a folding one, which is why we find this design on many ultra lightweight chairs. Again, main goal of an ultralight chair is to optimize efficiency. So, why is it more efficient? Well, there's fewer moving parts, so when the energy used by the client against the wheelchair rims of the rear wheels, when that force is moved forward the energy is transferred into the ground to move the chair forward, instead of into the moving parts of the frame. So, often, in a folding frame there's cross braces. And those cross braces open or fold the chair. When the chair is being propelled the cross braces can twist and move, even if you don't really see it. It might be a subtle movement. But they twist and move when crossing uneven surfaces. And a lot of the energy that the client is using to move the chair forward is actually lost in that folding mechanism, meaning that overall folding chairs are not as efficient.

There are some improvements, however, to folding frames. And this is showing a typical design of a side to side folding frame. Some folding frames now lock into place. So instead of only opening up this frame and simply pushing down on the seat rails until we seem to have reached our maximum width there's a locking mechanism. So when I push down it'll actually click into place. And that helps to rigidize the frame. It is not a rigid frame, it's a folding frame, but it locks into place. That minimizes some of the movement and loss of efficiency. There is still some movement, but this is a compromise so that people who really desire a folding frame have a slightly more efficient option. Folding frames as we saw in that last slide generally fold side to side. The cushion and back needs to be removed, unless this is a sling seat and back in order for the chair to be folded. I'm not a big fan of sling seat and back.

Occasionally, some adjustable tension upholstery in a back could be very appropriate for a client. But, typically, someone using an ultralight chair is going to require a appropriate cushion. So that's going to need to be removed. A lot of people prefer that side to side movement because it sometimes allows the chair to fit behind a seat in the vehicle, kind of sitting on the floorboard of the back seat. A rigid frame typically folds into a box. You can see in this picture the back canes fold down. There's usually a mechanism, a lever, or a pull string that's used. Just fold this down. The rear wheels can be removed simply with a push button. And in most rigid ultralight frames the footrests are actually part of the frame, rather than a removable swing away footrest, which is much more common in folding frames. This can then be placed on the back seat of the car, or on the passenger seat in the front, or in the rear of the car. This can impact transfer as well. Folding frames typically offer a swing away footrest hanger. So depending on how the client is transferring these swing out of the way leaving the front area of the wheelchair open. So the client can scoot forward and place their feet in front of the chair. Rigid frames, again, incorporate the footrest into the frame. That makes it lighter, there's less hardware that's required. It also rigidizes the frame further. The client can still transfer, but they either need to transfer side to side, or they need to land in front of this footplate. That's very possible, sometimes this footplate is tucked rather underneath the chair.

So typically on a rigid frame the knees are at about 90 degrees. And as this is part of the frame the footboard here sits squarely in-between these front casters without creating caster interference. Where with a swing away option like this if we were to pull these footplates back in a similar position, where a full-grown adult let's say has 90 degrees of knee flexion, these footplates are gonna run into the casters as they spin around. And that can be a problem. So, rigid frames incorporate the footplate into the frame. You could still transfer, but the client has to land in front of this or transfer side to side. This means the chair has a smaller footplate, it weighs less, and it rigidizes the frame further. This increases the strength of the frame. And if someone needs to keep their knees at 90 degrees without caster interference it's also a nice option. This study was, again, even though a bit dated now, an extremely important study. And it's often still referred to because of that. Hold on, there we go. Having a problem with my speaker, here we go.

A very important study where they looked at the durability of ultralight chairs versus durability of other chairs. Because many funny sources were saying ultralight chairs cost more than, say, a lightweight chair for example. And you know what, they're right, they do cost more. There's also a lot more design and features in these ultralight chairs. So they felt it was important to compare the cost-efficiency over the lifetime of the frame due to these funding concerns. And they found that over the lifetime of the frame ultralight chairs are much more efficient, cost-efficient, than less costly frames because of increased durability. So placing these wheelchairs on testing equipment that looked at their ability to stand how many times the wheelchair rear wheels could turn for example, a drop off test where they repeatedly dropped the chair over a certain height to simulate say rolling off of a curb. In all these various studies the chairs that were ultralight configuration were much more durable than any other category including lightweight. There's a number of design features that are very important. And we're going to discuss many of these throughout this presentation. There's all these factors that need to be considered when we are recommending an ultralight manual chair.

So, let's go ahead and take a look. First is weight. Now, we already know that ultralights are our lightest weight manual wheelchair option. And the lighter the wheelchair the more efficient it is to propel. This also includes the weight of the components and the seating. So if we've recommended an ultralight chair for someone, great, but we don't wanna recommend an incredibly heavy seat and back on that same frame. And now we have negated the advantage of this lightweight chair, so we need to keep in mind seating options that are also lightweight. Rigid frames are generally that much lighter than folding options because, again, there's a lack of those additional moving parts. Seat width. For someone who's using an ultralight chair self-propulsion is the goal. We need the frame to be as narrow as possible. At or slightly more than the measured hip width. If the wheels are too wide in relation to the client, then the client as they are self-propelling are going to tend to abduct their shoulders. And a greater degree of wrist flexion will be required during propulsion. This makes propulsion more difficult, even though the client probably can achieve it. It's not as efficient, and there's a higher risk of injury. So we want those tires in real, real close because of that. Now, some people are concerned about the wheels being too tight because the client might grow, they might gain some weight. Or because of the clothing, the tires tend to rub on clothes. Depending on the frame, if the client gets a little wider there's often some adjustment for that within the frame. So we should still place these rear wheels in an optimal location. If the clothing is rubbing on these rear wheels, and that can certainly happen right in this area here, there are clothing guards that are available from these manufacturers that are quite thin, to protect clothing from that rubbing. Clothing can get quite dirty. These tires pick up a lot of dirt during propulsion, and it can land right on the clothes. So clothing guards really help with that.

Seat depth is important to look at too when we are choosing a ultralight chair for a client. If the seat depth is too short as it is here, we see too much space between the back of the knee and the front of the cushion, this is gonna increase the load on the buttocks. We want that load to be well-distributed between the posterior thighs and the buttocks. Too short shortens the frame length and the amount of weight over the casters. And that decreases propulsion efficiency. We'll talk about this a little more in this course. But it's very important to look at driving efficiency where the weight of the client is in relation to the rear wheels and the front casters. If the seat depth is too long there'll be pressure behind the knees. And this might pull the client forward into a posterior pelvic tilt because the client simply can't scoot back far enough if the cushion is overlong. Ideally, we want to maximize weight on the rear wheels. That increases propulsion efficiency and maneuverability. The ideal length mostly for adults is at least two inches shorter than the measured seat depth. This allows depending on the placement of the feet there to be room for the calf. Now, this is gonna vary from person to person. The supplier can help out with these measurements as well. And with children because their leg length is already shorter than adults we may want a smaller measurement here, more Like a one-inch measurement. We then look at the height from the top of the seat to the footplate surface. We want to make sure we have the best length there because we have to include the height of the cushion in there. If the seat to footrest length is too high, then the knees will be higher than the pelvis. The distal posterior thigh may be unweighted. And this is gonna put more weight back on those ischial tuberosities under the pelvis. So we want to ideally support the thighs and the buttocks while supporting the feet, really distributing that weight. If the footplates are too low, then this client will not have enough support and stability. It's really important to us when we're seeking out stability to plant our feet to gain that support and stability from that contact.

Also, if the footplates are too low kinda like a lowrider car we might have ground clearance issue. So as a client is moving through their environment the bottom of the footplates can actually scrape. We don't want that to occur either. In these ultralights we have something called the front frame bend, well, what is that? That is the angle of the front frame right here in relation to the floor surface. This determines the position of the footrest relative to the seat. Is the footrest further back or further forward? A larger angle moves it further back. That's gonna result in increased knee flexion for the client. It makes the chair shorter and more maneuverable. And it helps to accommodate tight hamstrings, which a lot of our clients have. However, if we chronically place the feet well back we can actually cause shortened hamstrings. If we have a smaller angle, meaning we move this forward a bit, and we're increasing the extension, the chair is longer and less maneuverable. And if someone does have tight hamstrings we're gonna pull on that hamstring. That hamstring crosses the knee and the pelvis. And we can pull someone into a posterior pelvic tilt. We also need to look at seat height and vertical wheel position.

So, how do we determine what the height should be of the seat in relation to the ground? Well, chiefly, we're going to determine this by the length of the legs. So if somebody is six-foot-five, and maybe their friend is five-foot-nothin', they're going to have different seat to floor heights. We have to raise that taller person higher. Now, that can impact accessibility, like tucking under a table in a restaurant. But the other option is the feet dragging on the ground, we can't do that either. For the footplates to clear they need to be at least two inches off the ground. Depending on the environment someone is in they may need to even be a little higher. Again, if someone's quite tall this can impact their accessibility unfortunately. But it's a rather unavoidable situation. Now, that's the front of the seat, right here, knees to ground. But the rear seat height may be different. This is something unique in ultralight manual wheelchairs. When we're looking at a standard wheelchair that seat rail is fairly parallel to the floor. But in ultralight chairs we can adjust this so that the rear seat height can be either slightly lower or slightly higher than the front seat height. Why would we do that?

Well, because we need to first accommodate the lower leg length. We then have to achieve the right relationship with the vertical wheel height so that as the person is pushing their elbow is about at 120 degrees of flexion when their hand is resting on the top of the wheel. Now, this gentleman has his hand forward on the wheel a little bit in this picture. But when the hand is resting right on the top of the wheel the elbow should be flexed at about 120 degrees. If it's not we may have to adjust the rear seat height. And this is why sometimes the rear seat height and the front seat height are not equal. There's a lot of math involved here, and I'm sorry. Math is not my best subject. Here's a little more math, and this has to do with the seat slope. The seat slope is the difference between the front and rear seat heights. So if because of reasons we just discussed there's a discrepancy in height between the front and the rear there'll be a slope to the seat, either an anterior or posterior slope. This can impact sitting balance, transfers, and wheel access.

Usually, a minimum of two-inch slope is used. And typically it's with the rear of the seat being lower than the front of the seat. This slope may help someone who has less trunk control. It may make transfers more difficult, though, because now I have to kind of climb out of my seat in my wheelchair. And the user if the slope is really large, and that rear end of the seat is rather low, the user may end up too low in relation to the wheels to allow for effective self-propulsion. Another measurement we need to keep in mind, again, this is something the supplier is invaluable with in helping us determine all of these various factors is the backrest height and angle. Now, the taller the back the more trunk stability someone's going to have. It's gonna provide them the support that they need. But if the back is lower it's going to allow the scapulae to move during propulsion. That provides greater shoulder motion and decreases how often someone has to reach out and push against those wheels. So imagine you're reaching back to get a nice long stroke on that wheel. Your scapulae need to move. If the back's below your scapula we have more movement. So if someone using an ultralight chair can tolerate that degree of support in terms of the postural support and stability they receive this is a frequent height that's used in ultralight chairs. We also have to determine in our evaluation the seat to back angle that's going to work best for the client. This is often determined during the MAT assessment.

Again, this course here today is part of a series of courses, and one of the courses is about the MAT assessment. And that goes into a little more detail about determining the seat to back angle. The higher the back also impacts the sitting balance and position of the client. So if someone has very poor sitting balance they may require a little taller back. And sometimes a back is positioned so that the client actually is in a slight degree of anterior pelvic tilt because this position can often assist with self-propulsion. A little more math here and this involves center of gravity. You know, center of gravity is basically how do we balance? And in this picture here you can see someone performing a wheelie.

Now, wheelies are a skill that we sometimes teach someone who's using a manual wheelchair, particularly someone who's using an ultralight chair. In order to perform a wheelie someone has to have a very finely-tuned center of gravity to do this successfully and safely. Even for clients who are not regularly popping a wheelie the center of gravity still affects the overall performance of the chair including self-propulsion. By adjusting the placement of the rear wheel in relation to the chair, either forward or back, this is going to affect center of gravity. Now, the further forward the rear wheel is this puts more weight from the user onto the rear wheels. But it's a less stable position. It does make it easier to pop a wheelie. But we don't want this person landing on their head either. If we move that rear wheel further back it puts the weight more in-between the rear wheel and the caster, which is more stable, but is not quite as efficient for self-propulsion. So a big part of configuring the ultralight chair is determining the very best placement of that rear wheel forward or back. For efficient self-propulsion, the most efficient we can, the wheels should be as far forward as possible without impacting stability. We want to make sure that this person isn't going to easily tip rearward.

How do we figure out where that is? Well, one guideline that was proposed by the Paralyzed Veteran's of America's guidelines in 2005 was that when the client is allowing their arm to simply hang down on their sides when they are sitting in the wheelchair the tip of the middle finger should line up with the axle of the wheel, so right here. If that is occurring, not during a wheelie, but when someone's simply sitting in their chair and letting their arm hang to the side, that's most commonly where the rear wheel will end up. It's a good starting point. And from there individual needs might dictate a little more movement. Another way of determining center of gravity is to have the client sit in their manual wheelchair again and push forward. If the casters keep popping up off the ground a bit the rear wheel is too far forward. And that's not going to provide efficient self-propulsion. It needs to be moved back a little bit. But the user should still be able to pop that wheelie as needed. This also indicates the center of gravity is correct. Another geometry type measurement today is camber. In a fairly standard wheelchair the rear wheels are perpendicular to the seat and to the ground. But camber increases this angle in relation to the ground. Now, this chair here has a very significant camber because it's designed for tennis. So it has a very unique application, right? But by increasing camber slightly for a client using an ultralight chair we can improve propulsion because the wheel is a little closer to the body. With increased lateral stability, and that can help a person maneuver a little more readily, so they can make a turn a little quicker and with more stability. Increasing camber does increase the overall width of the wheelchair a little bit at the base of the wheels. And a typical camber that isn't really gonna interfere with going through doorways or anything but we can still have a benefit to the user is about two or five degrees. This often has to be determined at the time the wheelchair is ordered and is not always something that can be adjusted later on in the field so to speak.

So it's important to keep in mind. Wheel size is something that's also determined at the evaluation. For kids a rear wheel size that's very common is somewhere between 18 and 22 inches. And that's going to simply depend on the size of the child. In adults, 24-inch is most common. But some adults go as large as 26, particularly a taller adult. This allows us to raise those footplates higher off the ground. The wheel size is also determined by the height required to maintain that elbow at 120 degrees while the hand is resting on the wheel. This is dependent on arm length, again, the overall height of the client themselves. There are two main tires that are used in manual wheelchairs. And the one most commonly used for self-propellers are pneumatic tires. Pneumatic tires have the drawback of losing some pressure. Some of the air can get out of them just like with you bicycle, and they can go flat. But there's less rolling resistance when the client is pushing, which means I don't have to work as hard to push the chair. And, generally, these are more comfortable to use. They absorb some of the vibration, and jars, and jolts of the road. Solid tires, we're gonna feel that vibration more. It's a little harder to push, but there's less maintenance. There are various size casters as well that are available. The smaller the caster the better maneuverability the client's going to have. But there's more rolling resistance, meaning I have to push a little harder to make my chair go. And they can get caught more easily in obstacles such as larger cracks in the sidewalk. Larger are better for varied terrain, but they're just not as maneuverable. If someone spends time in both environments, varied terrain, but also say a lot of smooth level surfaces, sometimes we can get something kind of in-between these two. Now, in terms of position of the front caster the shorter the distance between the rear wheel and the caster the less rolling resistance there is, meaning the client doesn't have to push as hard. If we place the casters lateral to the outside of the footplates it decreases maneuverability because the manual wheelchair is wider at this location.

So on some rigid frames where the footplate is built into the frame itself these little casters are placed laterally to that static footboard. With swing away footrests, often, the casters are placed closer together. Now, it depends on the frame design. But, again, this is just another feature to keep in mind during our recommendations. A big challenge in self-propulsion is caster loading. It is important to make sure the client isn't over the front casters. We want the client's weight over primarily the rear wheel. If the client's too far forward we have a lot more weight on the casters. And that means that they don't turn as easily. The client has to work a little harder. We also have more wear and tear of the casters themselves.

Another consideration are handrims. Standard hand rims can be slippery, and that can make it hard to push. We could lose some of our force that we're trying to exert into the tire on the handrim instead. There are coated handrims out there that can improve propulsion, especially if the client doesn't have a strong hand function. Maybe they don't have a strong grip. But they do create friction, and this can even lead to abrasions, especially if someone's trying to slow down if they're going down a ramp. Some people use gloves to provide more friction against the handrim and protect the hands. And others will use special ergonomic handrims. These ergonomic handrims have been shown to decrease pain in both the wrists and the hands during self-propulsion. Another consideration is proper configuration of the axle and casters. This is going to decrease rolling resistance, again, the amount of force required to propel the manual chair and reduce the frequency that the client needs to push against the tires to achieve and maintain their speed. A big part of increasing efficiency of propulsion and decreasing repetitive stress risk is the type of propulsion technique that the client uses. There are several different types of patterns people use. And these are characterized in this graph here from another article that we'll find in our references. There's four most common patterns that people tend to use. And this has been determined, again, through research. Of these the single loop is the most common pattern that people use. But research has shown that a semicircular pattern is actually the most efficient.

So here in the first picture is this semi-loop pattern, where people tend to move forward and bring their arm back. This semicircular pattern tends to be more efficient. The hand tends to remain the below the handrim during the recovery phase of propulsion. So after pushing the hand falls down and comes back up again at the rear of the tire. This results in lower push frequency. I don't have to push as often. And decreased force is required in comparison to our other patterns. Other patterns include this arc pattern, back and forth, very inefficient, or this figure eight pattern. People self-propel manual chairs, particularly over a long period of time are at high risk of pain and repetitive stress injuries. Research has shown that the incident of carpal tunnel syndrome can be between 49 and 73% in people who self-propel. And about 59% of people who self-propel experience pain in the upper extremities or tears to the rotator cuff. This pain and injury can lead to less function. I can't push my chair as well. And I might have decreased function in other areas of life, as well as an overall decreased quality of life and increased medical cost.

So important to do everything we can to optimize self-propulsion, optimize the configuration of the chair to do so, and the propulsion method to mitigate these issues. Now, if you need help in finding resources to train the clients that you're working with to use their wheelchair optimally. There are several programs out there. It is important to train people who are just receiving their ultralight chair in how to perform a efficient transfer, how to perform a wheelie, how to get back into their wheelchair if they fall out of the wheelchair, and general maintenance of the wheelchair. These are covered in programs such as the manual wheelchair training guide. And it's available at this website here and picture to the right. There's also a very strong program called the Wheelchair Skills Program, it's available out of Canada, that you can check out online as well.

All right, we are going to wrap up with a case study. And in this case study we're gonna take a look at Lori. Lori has cerebral palsy and arthritis, she's 35 years old. She is already using an ultralight manual wheelchair and seating system. When she came in for evaluation she was looking to improve her postural support and stability. She wanted to see if her seated posture could help to control her tone. She has a lot of extension in her legs. She wanted to optimize her self-propulsion and optimize her activities of daily living. Her current equipment included a TiLite TR ultralight manual wheelchair, a Ride Designs custom cushion, and a Jay 3 back. This is an off-the-shelf back and a semi-custom cushion. In this seating system she was seated in a mild to moderate posterior pelvic tilt with mild pelvic obliquity and rotation, all of which could be reduced by hand. We could get her to a neutral position. But this was a position she tended to fall into over time. She was leaning somewhat to her right, though we could correct that, and has some kyphosis in her trunk that was non-reducible. Her lower extremities tended to windsweep to the left slightly and tended to be adducted. Her seat width was appropriate, she seated close to the wheels.

And you can see here she has some clothing guards, these plastic rigid pieces to protect her clothing from those rear wheels. The seat depth seemed to be a little long. It's right here against her calves, though the front seat is beveled back to allow for the fleshy part of the calf. Her seat to footrest height appear to be good. We had good pressure distribution along the buttocks, the thighs, and the feet themselves. And she had adequate clearance beneath the footrests. Her front frame bend was about 90 degrees. She was tolerating this degree of knee flexion well. It also seemed to control her tone and minimize the footprint of the chair itself, the size of the chair. Now, when we looked at the vertical height of the chair itself she's too high in relation to the chair. If her hand was down at her side her fingers wouldn't quite reach this axle. So she was positioned rather high in relation to the wheel. Either we needed to lower her in relation to the wheel or perhaps consider a larger rear wheel. Her current seat slope is slightly lower in the rear than the front. And when looking at her back height we actually increased the height of the backrest. Though the top of the backrest remained right underneath her scapula because although we got a taller height we lowered the back to give her more support behind the pelvis.

So we mounted the new back lower in order to give her that support. So the top of the back ended up still under her scapulas. The backrest angle had to be a little open to accommodate for that kyphosis. We looked at her center of gravity and noticed that when her arm was dropped her middle finger was in line with the axle right here, but again, above the axle. She's seated too high, though the relationship between the rear wheel and this front caster, this very small front caster was good in terms of center of gravity. But, again, she's just too high. She did not appear to have any camber on her chair. This would've brought the wheels in a little bit. But she was happy with the current configuration. She didn't have any stability issues, so we decided not to increase the camber. In the rear wheels she had solid inserts. This increased the weight of the wheel and the rolling resistance, but required less maintenance. And her caregivers preferred that. She has very small front casters as you can see, though she is not having any issues with them, and is mostly using this indoors. The handrims have just a light coating to give her a little more friction so she's not slipping on them. That helps her with her propulsion. In terms of propulsion she could propel very well. She is unable to efficiently propel unless her legs are strapped because that extension takes over. And then she does not have the same level of function. So we recommended that we trial a lower seat to floor height in the back to improve the relationship to the rear wheel. Then, determine if that improved her self-propulsion. If that was unsuccessful, then we thought we could instead try a larger rear wheel. Both of these were an attempt to put her in a better relationship to the rear wheel for improved self-propulsion. If we used a larger rear wheel the frame would have to be reconfigured somewhat to accommodate that. We also told her that she could consider a slight camber and consider pneumatic inserts to lessen the weight of the tires. She decided not to pursue those. But those were things we recommended that she consider.

We also recommended a few seating changes that improved her overall stability. And as a result this improved her self-propulsion. As we wrap up our take home message with ultralights is that our goal is independent mobility. And that mobility needs to be as efficient as possible and limit repetitive stress injuries. If a client is not efficient in one category of manual wheelchair, then we can always consider the next category. And if a client's not efficient in any category of manual wheelchair we may need to be into power mobility. We have some resources listed here that you can refer to on your handout that can be helpful to you and provide further information and education, whoops, went a little too far. If you need to contact me here is my email. Again, this is on your handout. And if you want, again, to share any questions or comments that's absolutely fine. I want to thank you very much for your time here today. I appreciate it, I know everyone's very, very busy. Again, thanks everyone, I hope to see you soon at another webinar within this series.

- [Presenter] This brings us to the end of today's webinar. Thank you so much, Michelle, for sharing your knowledge and expertise with us. I hope everyone has a great rest of the day and you join us again soon on occupationaltherapy.com, thank you.