Walking Recovery Post Stroke

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- [Calista] Well, it is my pleasure to welcome back Dr. Jill Seale to PhysicalTherapy.com. Jill has been a licensed physical therapist for 24 years, and she received her board certification in the area of Neurologic Physical Therapy from the American Physical Therapy Board of Clinical Specialties in 2004 and was re-certified in 2014. She has practiced almost exclusively in the field of brain injury and stroke rehabilitation. And she has a variety of teaching experiences in physical therapy academia as well as the healthcare community at large. She is currently faculty in the DPT program at South College. In addition she teaches in several online onsite continuing education programs across the nation. She has taught and presented in the areas of neurologic pathology, rehabilitation, gait, orthotics, mentoring, and research, and is currently involved in a clinical research in stroke rehabilitation, orthotic management, and gait analysis and rehabilitation. Well, thank you so much for returning to physicaltherapy.com. Once again, Jill, we are pleased to have you here with us today. And at this time I'm going to turn the microphone over to you.

- [Jill] Okay, Calista, thanks so much. Thanks for having me back. I welcome everybody to the course. Thanks for joining us here in the afternoon for me. Maybe still in the morning for some of you on the West Coast I guess, but thanks for joining and participating in this discussion about walking recovery following stroke. This is a topic that I've spent a lot of time thinking about and working in and doing some research in and it's something I guess I might say is near and dear to my heart. And I have to pace myself because I will start to talk really fast and excited and try to tell you way too much stuff probably. So it is something I really enjoy talking about. So I hope you enjoy the talk as well. I will say the reference list that's provided there is not a complete all the references that are in the presentation, but in the presentation I did try to give you all the reference information in terms of the author and the source and the year. So I think you can find those references, but if you have any questions or want information more about a different reference, I'm happy to try and get that to you. So here's my

disclosure. I am going to receive an honorarium. I don't have any other sort of disclosure issues. I don't have any product ties or any of those things there. I do need to go over the learning outcomes for you or with you. After this course, participants will be able to identify at least four common gait deviations and the causative impairments experienced in persons post-stroke. Identify at least three appropriate outcome measures when creating an effective strategy for examination and evaluation of gait in persons post-stroke, identify at least three interventions found to be efficacious in the evidence for improving gait post-stroke, and identify at least one intervention technique and one orthotic prescription when creating a plan of care for gait recovery in persons following stroke. So those are the things that we've set out before us and where we really need to start is talking about normal.

So you may be saying, "Well, we're here to talk about gait and people with stroke. That's certainly not normal." But I can't help, but make the point that in order to understand any sort of abnormal gait in any type of patient, any type of person, we have to first have a really good understanding of normal. So I would encourage you, we will give just a really brief overview of normal. Normal could take a whole course by itself. A whole day course probably by itself. So I would encourage you if you feel like normal gait is something that you learned and maybe forgot or didn't learn all that well, that's a good place to start. Is to refresh yourself, get yourself in some sort of course where you really go back through and learn normal. You really have to have that committed and in your memory bank. Sort of in your toolbox that you carry around in your head. That's going to be the first step in understanding what's going on with our patients with stroke or any other sort of abnormality. So I really would advocate for that. And I will say that in some of the research that I've done, and then I'll talk about in a little bit, I will say that people seem to have a very wide varying understanding of gait. And we probably shouldn't have a wide and varying understanding, right? It's kind of a basic science. We should all pretty much be on the same page in terms of our understanding of normal gait. And when you talk to clinicians out there, both new

clinicians and seasoned clinicians who are considered maybe experts, there's still a lot of variability that shouldn't be there in understanding of normal gait. So go back and refresh yourself on normal. Get a really solid handle on that. That being, I will talk a little bit about some key things related to normal that we need to sort of nail down before we can go on and talk about the abnormal issues that we see in our patients with stroke. So I put just a little normative data here for you. I think it's important for us to remember. We don't really talk about cadence too much. That's steps per minute and you can see the normal range there. That's not a measure we use too often in our patients with stroke.

We definitely should be using velocity measures, right? We should definitely be looking at gait speed. And so the normal measures there: 82 meters per minute, or 1.37 meters per second. That's normal. It's also important to know that two meters per second is generally what's considered the standard of speed that's needed to cross the street. As I like to say, to cross the street before you get hit by the bus. And so that's important to keep in mind as well. That's significantly above what's considered the quote, unquote normal. One of the problems of online classes is you can't see when I do air quotes, right? So I have to say that while I'm standing here in my office at home doing that.

But it's important to know that there is a minimum speed that's needed for community mobility. There's a minimum speed that's really needed for even household mobility. I mean, that 1.37 meters per second is considered the normal, but that's not even fast enough to safely get us across most streets. Another really important normal that I always like to point out because I feel like a lot of people don't really take this into account and this is a big issue in our patients with stroke is that base of support. That's typically measure the heel-to-heel base of support. And as you can see there, two to four inches is pretty narrow. That's not a very wide base of support. And I would encourage you to kind of think for a moment, reflect on what your patients who have

had a stroke look like when they walk and what their typical base of support is like. I'm guessing that most of you are picturing a much wider base of support. And you're probably thinking, "Well, Jill, they widen their base of support to increase their stability." And that's true. And that seems like a good thing to do, right? Let me widen my base so I improve my stability. It does make me more stable, but it makes me a heck of a lot less dynamic. Walking is a dynamic activity. If I have a wide base of support, I'm decreasing my sort of capacity to be dynamic.

So I'll tell you just really quickly, you can do this wherever you are unless you're around strangers and they're going to look at you funny when you do this, but if you just stand up and stand with your feet about two to four inches apart, and maybe put your hand, your fist kind of at your belly button level, and then take a step forward with your right and make note how much your fist in your belly button moved to the side in order to be able to take that step. So you probably had to make a very small weight shift if you only had your feet two to four inches apart. Your marker that you have there of your center of mass, your fist and your belly button that only moved probably a small amount laterally.

Now, if you stand with your feet much further apart, you take a wider base of support. Say maybe a good foot which is what a lot of our patients will do. Some even more maybe, but take about 12 inches apart with your fist in your belly button again and you take that same step, you'll note that your fist has to shift a long way the distance that your center of mass moves. And I'm just using your fist there so you can sort of visualize where your center mass is. Your center mass has to move significantly one way or the other in order to be able to pick up your foot and be able to take that step. And so when our patients stand and walk with a wide base of support, they are actually making it so they have to weight shift more than what's normal. And what do our patients with stroke not do well? They don't weight shift well. So, we can certainly do some things to help them weight shift better, but we can also decrease the amount

of weight shift that's necessary by getting them to narrow their base of support. So one of the things I always look at is are my patients walking with a wide base of support? I'm going to come up with some ways that we can work on narrowing that down using some visual feedback, using some physical barriers or something to get them to walk with a more narrow base of support. And I know I hate to make promises, but I will strongly suggest to you that when you get your patient walking with a more narrow base of support, I'm already getting into interventions and I'm supposed to be talking about normal here, but when you get them to walk with a more narrow base of support, you'll see that their speed increases and their symmetry increases. They won't like it at first, they will not enjoy that.

They will feel unstable because we have essentially made them more unstable, but we've made them more dynamic. We've given them greater dynamic capacity. So did me to get on a soap box about that, but if I didn't say that now, I would probably forget it. As you heard, I've been doing this for 24 years. That means I'm old and my memory is short. So I have to say it when I'm thinking about it as my mother used to say. Moving on down the list of norms, we should all have a certain amount of toe out. About seven degrees. So don't worry if your patient has a little bit of toe out. That's normal. But here's the final four bullet points are really important. We spend 62% of the time in stance and 38% of the time in swing.

Now, I want you to remember that we spent almost twice as much time in stance as we do in swing because later on we're going to talk about the importance of stance and how we don't necessarily value stance or address stance. And I'm going to remind you that we spend much more time in stance than we do in swing. So it's important that we address both of them, but it's definitely important that we address stance. And if you look at the single limb and double limb support time, we should spend 80% of the time in single limb support and only 20% of the time in double limb support, right? So the faster we walk, the less time we're spending in double limb support, right? So, you're

running and then you're really spending no time in double limb support. So what happens in our patients with stroke though is they'll flip flop that last ratio, and they'll spend a significant amount of time in double limb support and much less time in swing limb support. In single limb support. Sorry, let me say that again. They'll spend a significant amount of time in double limb support, and they'll spend much less time in single limb support. So they'll flip flop that ratio the other direction. They'll also on their hemiparetic side, on their affected side, they'll spend much less time in stance on that side and much longer time in swing on that side.

So again, they sort of invert that relationship for their hemiparetic side, especially they really will change those ratios on both sides for swing and stance. So when we know that normal means that I spend 80% of my time in single limb support, that tells us something for us to be working on in our patients with stroke, right? How do I help to reestablish that stability in single limb support so I can get them more back towards that 80% of the time in single limb support? So again, to just give just a brief, it's kind of the cliff notes version of normal gait.

If you think about it, Perry described there being these three functional tasks within walking, weight acceptance, single limb support, and swing limb advancement. Within those then you can see that there's a total of eight sub-phases amongst those three functional tasks. So when we have weight acceptance, that starts with that initial contact, right? And the really important thing that should happen in initial contact is actually make a heel first contact. What do our patients do? They typically make a flat foot or even a forefoot contact. Why is that a problem? Well, it's going to change the mechanics of stance. It's going to create a period of instability. It takes away some of the stability and essentially disrupt then the rest of the stance phase. Loading response is the second of the sub-phases and the second part of weight acceptance. And that's where we slightly flex our knee eccentrically and we need a great deal of hip stability during this phase. And we also have some controlled plantar flexions. So our foot

comes down to the floor. So we've got the hips acting as a stabilizer, we have the quads acting as an eccentric muscle to lower the body, to flex the knee a little bit. We have the dorsi flexors acting eccentrically to lower the foot to the floor and to move us into some plantar flexion. And it's important to know things like those little details about that that's eccentric activity in those muscles, because if I'm going to retrain for that base in my patient that has a problem with that, I want to be retraining those specific types of muscle contractions. So I just throw that out there. Again it's a little nugget to keep in mind when you're thinking about how you apply what you know in normal to what we see in pathological.

We moved from there into single limb support where I said we need to be spending much more time. That's mid stance and terminal stance. And in mid stance, that's when our tibia is moving forward. We start in a plantar flex position and we start moving towards dorsiflexion, and actually into five degrees of dorsiflexion at the end of mid stance. And so with that controlled tibial advancement. At terminal stance, we push forward to 10 degrees of dorsiflexion. Our max degrees of dorsiflexion we get in all of gait, and then we stop that forward motion of the tibia and that stopping of the forward motion causes the heel to rise.

And that puts us in what we call the trailing limb position, where I'm in maximum hip extension, maximum knee extension, and maximum dorsiflexion. This is a really key phase. If this does not occur, and we'll talk about it a little bit more in a second, but if this doesn't occur, then swing limb doesn't happen normally, right? So we move from single limb support into swing limb advancement. That's the four phases of swing: Pre-swing, initial swing, mid swing and terminal swing. In pre-swing we get knee flexion. And that knee flexion is passive. We'll talk a little bit more about that in a second. The knee flexion I get in pre-swing which is 40 degrees is passive. And it happens because terminal stance happened correctly. A little bit more on that in a minute. In initial swing, I'm really getting a lot more hip flexion and additional knee

flexion. And my hip flexors are really driving that motion. Mid swing, my hip flexors are still working. They work throughout the whole four phases of swing, and I'm starting then to move my foot into neutral to keep it so that I can make that heel first contact. And then in terminal swing, the key thing there is that I get full knee extension. My quads come on to help me get my knee fully extended and keep it extended so that when I touch down for weight acceptance again, I'm ready to hit with the heel first contact. So quick rundown of the three functional tasks and the sub-phases. Now you might be saying, "Why do I care so much about a normal gait? Why would achieving normal gait be important?"

Well, you can probably think of some reasons why before you advance the slide or look at the next slide. You can think about maybe it's important to your patients. Maybe they want to walk more normally for any number of reasons: Better function, just to look better. To look like they're functioning more normally. Really the main reason that we want to achieve a more normal gait besides all of the patient-related issues which are important, the patient-related goals about that, but normal gait is all about energy conservation. The gait cycle is a beautifully tuned sort of process where at any moment that muscles can turn off and rest, they actually turn off and rest.

And so everything is programmed such that as many times as possible muscles are able to shut off and allow things like gravity and the alignment of the body bio-mechanically and the joints and the ligaments to be able to stabilize the joint and the muscles can actually turn off. So there's a lot of energy conservation that comes in normal gait. And every deviation from normal drives up the energy cost, right? So we want to be able to utilize things like normal momentum. Not abnormal momentum, but the normal momentum that's involved in walking and that passive positioning in order to be able to substitute for muscle activity. So you allow that selective relaxation of those muscles and thereby you're conserving energy, right? The other things to think about are any gait deviation increases the risk of falls. The more gait deviations a

person has, the greater their fall risk. Another really significant problem is whenever I have deviations in my walking that causes biomechanical stressors, I'm at risk for over-use and injuries. We're going to talk in a minute about how a common thing we see in patients with stroke is a knee extension thrust in stance. And you can imagine if I do that over and over, and I walk a lot and I try to be active and mobile and get out in the community and return to work, those kinds of things, it's not going to take very long before walking with that knee extensor thrust. Every step is going to lead to some knee breakdown, right? I'm going to have some problems in the joint. I'm going to disrupt the joint, wear down the joint, overstretch the capsule, over-lengthen ligaments. All those kinds of things, right?

And then more from a patient personal perspective, there's a lot of stigma involved when you don't walk normally. I have patients that tell me, "People assume I don't think too good or think too well because my walking doesn't look right." And so there's a lot of reasons that we want to address gait and try to return it to as normal as possible with energy conservation being a really big one. So I mentioned already a little bit about stance versus swing, and I reminded you that we spend more time in stance, we spend more time in single limb.

And yet what I'm going to suggest to you is that we're missing that in our assessment of the patient and we're missing that in our interventions with the patient. We're not really focusing on that stance phase, but we've already identified there's eight phases of gait. You may be thinking, "Man, I don't quite remember all of those phases we just ran through really quickly." Well, go back and relearn that. Look at that. But if you can't remember that right now, just hold on to that there's these two sub-phases or subclasses and that's stance and swing, right? And I worked with a group of people in Houston a few years back and we started spending some time talking about how we felt like therapists somehow neglected the stance phase. We felt like, and this was just sitting around. This is like nerd talk. I was about to say sitting around at happy hour, but

that makes me sound like a major nerd. So I'll say it was sitting around the therapy office, but it probably was a happy hour just so y'all know. But just sitting around we were like, we feel like we'd been studying a lot about normal gait and we were like stance phase is really important, but I don't really see therapists treating stance phase a lot, or I don't see them treating stance phase correctly based on what the most problems are in stance phase. And then we started talking about orthotics and we were like, I don't think people prescribe orthotics at all based on the stance phase a lot of times. So we just kind of had some of these conversations and came up with some of these ideas that we felt like were gospel truth, but we decided we should probably investigate that a little bit.

And so, thinking about that, yes, we spend a lot of time in stance. More time in stance than we do in swing. We spend more time in single limb support and we recognize that if we fix many of the stance problems, it seems to improve their swing phase problems. So we wanted to dig a little bit further into that. So we did some research that was just published last year. Myself and one of my colleagues from UTMB, Dr. Carolyn Utsey, and we did some qualitative research of groups of therapists across the nation. So we did some regional.

They're here in Texas. And then we did some that was nationwide. So there wasn't a regional bias. And we did focus groups where we asked them a series of open ended questions, but the main leading questions were, what do you see as the most common deviations in people that have had a stroke? Tell us what you feel like are the common ways that they walk? And so you the audience can be thinking about that too. You can answer that question. And then we asked them to follow that with, what do you think are the major impairments that cause those deviations that you've identified? We also asked them about how they assessed walking in patients with stroke. Like what their method was or what was included in their assessment or their examination evaluation of patients walking after a stroke. And then we asked them about their philosophy

related to orthotics. And so I'm just going to unpack a little bit from this study. There was several themes that were identified, but one of the things that was evident right away was that they most commonly identified and described and addressed the swing phase. Probably in every one of these conversations that we had, the first thing that a person replied in terms of the most common deviations, it was something that had to do with swing.

And if you were to count them up, the number of comments about swing were much higher than the number of comments around stance. And they pretty much all described very limited and similar problems with stance and didn't really get quite at the heart of that, but I'll talk about that in a second. But they really latched onto the swing phase. And they also talked about in their treatment of patients with stroke, their treatment tended to focus on the swing phase of gait as well. So they identified it, they described it, and they addressed swing phase way more than they did stance phase based on their discussions with us. We also know that swing phase is greatly dependent on the stance phase. If stance is not normal, it will disrupt swing phase.

And especially pre-swing is very susceptible to any sort of problems that go on in terminal stance. Swing phase is fairly easy to compensate for in terms of distal impairments like a lack of dorsiflexion in swing. That's very easy to compensate for either with a very minimal orthotic device, ACE wrap. I joke that you could fix the swing phase problem at the ankle with duct tape and string. I don't really advocate for that, but just saying that it's a pretty easy problem to fix distally. There's proximal swing phase problems we'll talk about in a second, but whatever solution we give to fix the problem that's going on at the ankle, not enough dorsiflexion, lack of active dorsiflexion, if we give them an orthosis for that, it doesn't completely reestablish swing phase clearance because swing phase is also highly dependent on the hip flexors. So you guys have all seen this, right? You put an AFO on a patient, they don't drag their toe, but they still drag the limb. They still have difficulty advancing the limb.

So we fix the clearance at the ankle. They have the capacity to clear at the ankle, but they don't have the strength and the power and the timing, but really strength and power are big of the three there. At the hip they still won't be able to clear that limb. They won't have swing phase normally, right? And you'll see that they still struggle with swing phase. So that's important to keep in mind. We talked about, or I already alluded to that swing depends on stance. And let me just go a little bit further into that. I said earlier that the knee flexion and pre-swing occurs passively. In pre-swing we get 40 degrees of knee flexion. That's where the leg, a lot of people say it unlocks and gets ready to swing. And you know that in many of our patients with stroke, it does not unlock. It stays stiff. And we'll see a video example of that coming up. But stay stiff and therefore they then have an extra problem sort of advancing the leg. But to go back to what should happen, that knee flexion should occur passively. What causes that passive knee flexion to happen?

It's caused by the heel rising. What causes the heel to rise? It's the plantar flexors acting in terminal stance. So if you take your hands and put it horizontally in front of you, and then you take your other hand and you put it vertically and you make sort of a tibia of your vertical hand and a foot of of your horizontal hand, right? So hopefully you're all doing that. In mid stance, my tibia is coming from back and plantar flexion to about five degrees of dorsiflexion. And then in terminal stance, it comes to 10 degrees of dorsiflexion, and then it stops. It should stop. What stops it? The plantar flexors don't allow it to go any further. They've been controlling it eccentrically as it comes forward, and then when it gets to about 10 degrees of dorsiflexion, the plantar flexors sort of lock down the tibia and don't allow it to go any further. And you'll hear some people say that it makes the tibia and the foot become a rigid lever. There are no longer two pieces moving on each other. They're a fixed piece together, right? Does if that makes sense? Hopefully you can picture that. So the tibia stops. The plantar flexors put the brakes on the tibia and it can't go any further forward. But what's happening on the other limb? Is it's continuing to swing on by, right? It's generating momentum that's

carrying the person forward. That forward momentum now is going to take that tibia and foot which are now a fixed rigid lever and it's going to have to continue to go forward because momentum is taking it forward, but it can't dorsiflex anymore, so the heel will rise. Does that make sense? Now, if we're walking faster for running, we're actually propelling ourselves off and that's what's causing the heel to rise. But I can get that same heel rise just by the passive stopping of the tibia going forward. And in most normal walking we think that's what occurs. The tibia stops going forward because the action of the plantar flexors: The gastroc, the soleus. There's actually seven total of them. I think all of your toe flexors get involved there. The plantar flexors stop the tibia from going forward.

Momentum is continuing to push the body forward so the heel rises. When the heel rises, it causes the knee to flex, okay? I pause for a second 'cause I want you to picture that. The heel rises, it causes the knee to flex, okay? That passive knee flexion occurs because of the plantar flexors stopping the tibia from going forward in terminal stance. So when you're seeing that person that has that stiff knee gait, that they're not flexing that knee in swing, and you focus on the swing phase, you try to get them to actively flex their knee or any actively flex their hip or any of those things. You're really focusing on the wrong thing.

Not a bad thing. Those could all potentially help, but they're not helping with the problem of the knee not initially flexing. If you want to help the knee flex initially, you got to come back and figure out how to fix terminal stance and how to get that tibia to stop going forward. To be controlled. To come forward in the first place and be controlled. And that centers around the plantar flexors. And we'll continue to talk about them as we move forward because that's a big problem in our patients with stroke. Big, big problem. So if we talk about the stance phase now, stability in the stance phase occurs. We can kind of think about it whether looking at it early and looking at it late. So early in stance, stability is driven by the quadriceps and the hip extensors to

some degree as well. But we said that loading response, that's a big eccentric moment for the quadriceps to manage, right? That early from initial contact into loading response, that's a lot of eccentric activity that happens at the quadriceps. So when you see instability early, that's oftentimes a quadriceps issue versus instability that occurs in the mid to late stance, that's driven by the plantar flexors. That stability occurs by the plantar flexors. In mid to late stance, just to remind you of normal gait, normal muscle function during gait, the quadriceps and the hip extensors go off. They aren't working in mid to late stance. After the very initial part of mid stance, they're completely silent.

They're in their rest phase and the plantar flexors are controlling the forward progression of the body from just shortly after the beginning of mid stance through terminal stance, okay? So when we see that lack of stability early, that's going to look like that the person hits the ground and as soon as their foot contacts the ground, they're going to immediately hyper-extend their knee and they're going to keep it hyper-extended through the entire stance phase. And that's somebody with quadriceps weakness.

And we don't see that as often in patients with stroke. We typically see somebody who has a little bit later stance instability, they will either just keep their knees slightly crouched throughout stance or they'll hit the ground, they'll start to shift their weight forward, and then they'll have an extensor thrust that occurs in really late loading or mid. Usually mid or terminal stance. When we see that, that's a plantar flexor issue. If it's a muscle weakness issue, that's an issue with the plantar flexors not being able to stabilize and hold the tibia and allow it to go forward. So the body says, "Hey, if I let my tibia go forward, I'm going to buckle and fall. So I'm just going to push it in the other direction. I'm going to use my quadriceps which were a little bit stronger to push my knee into sort of that safe extensor thrust, hyperextension position." Okay? So hopefully everybody can picture the difference there between early and late stability

issues in stance, okay? And we'll talk a little bit more and I'll show you a video of that. How that looks either as knee flexion or an extensor thrust. So if I could show that first video, so this is a gentlemen... Oh, didn't seem to be there. I can't... So, Kathleen I'm hitting play, but nothing's happening. Oh, it's playing on your end. Oh, well, hmm. So, I'm going to picture what's happening. I don't know if there's a way Kathleen to get it so I can see it. I can't... Oh, there we go. There we go. Perfect. Perfect. Thank you. So this is a gentleman that is keeping that slight crouch in the stance phase. So you're looking at his left leg just in stance really at this point 'cause we're just talking about stance, but you can see that he's in too much dorsiflexion at his ankle during stance and too much knee flexion during stance and too much hip flexion during stance. I often refer to him as flexion man.

But he's keeping that slight amount of crouch. So this is an instability in stance where he's choosing to just let his quadriceps work the whole time. His quadriceps are having to stay on to support him. This is not a quadriceps weakness. His quadriceps are actually whats supporting him every step because he's keeping his knee slightly crouched. So hopefully everybody can see what we're talking about here. Now, most times when I see a therapist watch a person that looks like this, and I'm actually going to take it back and we're going to watch it from the side for what we're talking about here. A lot of therapists will look at this and they'll say, "Well, they have quadriceps weakness." At which point I say, "Everybody's stand up, get in a crouch and just hold that here while I continue talking to you or walk across the room while I continue talking to you." And you'll see really quickly that your quadriceps are working a lot, right? Think about children with CP that walk in a crouch all the time. Their quadriceps are at a 10 out of five. So what's happening here is this gentleman has zero plantar flexor activation and he doesn't volitionally choose this strategy, but his body has learned, if I let my knee straighten and my tibia come forward as it should, there's nothing to control that forward motion. So I'm just gonna stay in this little crouch the whole time and not have those normal mechanics. Now, what are the problems here? This person

is burning a lot of extra energy every step via the quadriceps to keep that position and to not go ahead and collapse to the floor. So that's that choosing the crouch position. So if I go watch the second video now. Kathleen, thank you. This gentleman is doing the extensor thrust. He makes contact, he starts to shift forward and then he pushes that knee back rapidly, right? Everybody can picture that this guy's going faster than that other guy. So you have to look a little bit faster. So let me play it. Start that one over again. But this man is choosing that extensor thrust. The other thing that's different about this gentleman that we haven't talked about yet which we will talk more in detail as we go forward, is this gentleman also has a plantar flexion contracture. He lacks range at his ankle and that lack of range also pushes him into that extensor thrust, right?

So this gentleman actually has really strong quadricep, but he has very weak plantar flexors and he has a very tight gastroc so that he doesn't have full range to get into that 10 degrees of dorsiflexion that's necessary for terminal stance. So I use these two videos because these two gentlemen have very similar problems. A, they both had a stroke, B, they both have stance instability and C, their stance instability for both of them has to do with weakness in the plantar flexors. The second gentleman has a range of motion restriction that the first gentleman doesn't have. Now, the other thing that you can think about, which I think.. I don't want to make everything seem completely labeled and everybody fits into a nice, neat pattern, but this gentleman here is more in the chronic phase of stroke. He's actually several years post-stroke, one reason why he's developed such, he has a contracture at this point. The other gentlemen who had too much flexion in stance, he was early on in his recovery I would guess. I can't really recall exactly, but I would guess just a couple of weeks out from his stroke. And I think, although again I don't want to make everybody cookie cutters, I think that's a pretty common pattern that we see, right? Early on patients tend to be lower tone. Don't have much in the way of range of motion restrictions, but they have really big issues with activation or lack of activation. And so they will oftentimes choose

more of that flexor pattern as they start to walk more and try to walk faster. For efficiency sake they start relying on their quadriceps which tends to be their muscle that starts working the quickest or doesn't ever stop working completely. And they'll start to develop this extensor thrust pattern that this gentleman has. And then also of course, tightness develops over time as well. So, let's go back to the slides. So hopefully those two videos can, I mean, I'm guessing you all are thinking, yes, I've seen both of those patients, right?

I've seen somebody that looks like both of them. And so I don't know what you thought when you looked at those patients before, whether this is kind of thinking about it in a new way or not, but we're seeing really the same sorts of primary issues. Their stance phase instability. There's definitely problems going on in swing and we'll talk about those later and I'll use a different example to talk about it as well, but I just really wanted to hone in on what's going on in those two gentlemen in terms of their stance instability.

So, in terms of what the current understanding and focus of in gait following stroke, again based on our research, there's this focus on swing limb dysfunction. And I've kind of already suggested that. I laughingly call a swing limb eye candy for gait. There's just something about the swing phase that our eyes are attracted to and we see really easily. It's also much easier to understand swing because it's just the limb moving on the body versus stance phase is the limb moving on the body and the ground then reacting to that movement and reacting back, right? So that muddies the waters and make stance much more complicated. So we tend to focus for whatever reasons on swing limb dysfunction more based on our research. When we ask questions about the causative factors, when we got people to identify the gait deviations that they saw as common, we follow that up with, what do you think are the reasons why they have those gait deviations? What's weak? What's tight? Sensory loss. What are the impairments that go with those? And there was a lot of focus on proximal impairments.

Lots of focus on the trunk and the hips. And that's not to say that the trunk and the hips aren't important. They certainly are, but there was much more proximal focus than there was distal focus. And there was little to really close to none identification as the plantar flexors and plantar flexor weakness as a contributing factor to the problems that they were seeing. They oftentimes didn't identify weakness in the plantar flexors as the cause of stance instability. They would see, they would talk about, they would describe those two gentlemen perfectly. Well, you can see patients that walk like this or walk like that. And many of them really in their mind they saw that patient that had that extensor thrust.

That second patient I showed. That was really the description that more of them gave us. Was that gentleman. And so they would identify that they had a stance phase problem. They would talk about that knee extension or hyperextension many of them called it. It's really an extensor thrust that happens. But they would describe that, but when you ask them about causative factors, they didn't relate the plantar flexors as being a potential causative problem there. They talked about the quadriceps or the hip extensors, but they didn't really talk about the plantar flexors. And again, when you do qualitative research, you get to utilize some quotes from the participants to highlight and the themes that you found.

And that's always kind of interesting. So there are a couple of quotes that I put there. And these happened to be from people in our expert panel. They said, one person said, "Stance phase doesn't bother me, but swing phase you have to clear the foot." They were really focused on the swing phase is what bothered them. Stance phase they really didn't pay it much attention based on what they said, but the swing phase you really have to focus on clearing the foot. I always follow that up by saying the stance phase actually keeps me awake at night trying to think about what to do for that. But again, that makes me sound particularly nerdy. So, and then there were people, one person said, "You got to control that foot drop." That's always the first

priority. And what I wanted to do there was to give you sort of two things: An overview of normal juxtaposed with how's that normal disrupted in stroke? So hopefully you have that. Hopefully have a little refresher about what what's going on in normal. Reminder about that, but then also you're able to overlay what you already knew, what you already see at least in your patients with stroke on top of it. So how do we analyze gait? What do we do? What's our gait examination and evaluation procedure post-stroke?

Well, I think for most of us and for all the people in our research, they all talked about doing observational analysis and they would many of them talk about having a systematic way of doing observational analysis. But then when we would ask them more about that system, everybody's system was different. Some people used a particular form that they followed, some people just had stuff in their mind and wrote stuff down. There was really no consistency in their systematic approach between participants.

A few people talked about objective outcome measures. And what I'm going to suggest to you is that we need to do a very good observational analysis. Yes, that is still what we mostly are going to do. Not many of us walk around with the gait lab in our pocket. So we're still going to rely on our observational gait analysis. We're going to talk about how to improve that and we're going to talk about the necessity of combining that with some objective outcome measures. So observational analysis certainly has its advantages, right? It's free, it's our eyes and our brain. We don't have to purchase expensive equipment. We can take it with us everywhere, right? Disadvantages are: It's inherently unreliable. The reliability is moderate at best for that. And that's within the same person and then when you compare that across people, reliability really goes down. So it's very unreliable. Our eyes are relatively slow. And so walking can be a speedy thing or somewhat speedy thing. So we're just not really equipped to be able to capture everything that's necessary to capture with our eyes.

It's still what we have to use. There are ways that we can maximize that. And I'm sure you can think of some. If you have the option to video tape, it's funny we all say videotape. If you have the option to digitally record your patient walking so that then you can just have them do one walk, and then you can watch it as many times as you need to, that's a good way to improve accuracy of your analysis because you're only having the patient walk once. Their walk should be pretty steady. Not going to change over time. And then you can go back and watch that as many times you want, slow it down. I know it's getting harder and harder to be able to do that videotaping, but that would be great. Having a standardized view. So whether you're watching or videotaping, making sure that you're watching from the side. So you have a clear sagittal view.

So you're directly perpendicular to the person and you watch them walk by and you try to keep your head pretty much still and watch them walk in front of you. When you're moving your head or if you're videotaping them and you move the camera or your phone or whatever it is that you have, that disrupts. When two things are moving, that makes it much harder to figure out what's happening when you look at that recording.

So those are a couple things that you can do to improve the accuracy. Also make sure that you watch them from the front and the back, right? We want to get that good sagittal view, but then we want to get a posterior and an anterior view as well. So I already mentioned that there was a lack of systematic approach. A lack of consistency between subjects and only the expert group in our research talked about use of outcome measures, talked about assessing in different environments or maybe assessing under different conditions like a dual task, and only the expert group talked about energy efficiency and the importance of that and trying to get some estimation of their energy efficiency and only experts interestingly enough talked about patient autonomy involved in the analysis examination, evaluation process. So we all do this observational gait analysis, but I'd be interested to know. And you can put in the chat

box if you have a system that you use. I love to see that, but if you have any tool that you use for your observational gait analysis. Many of us just watch the patient walk and maybe write some stuff down or type some stuff in these days. Some of us may have some check boxes on a piece of paper or in a electronic medical record where we can check certain things related to their observational gait analysis. Many of us learned to use the Racho Forum which is the last bullet here. The Racho Los Amigos Observational Gait Analysis system. That's a great tool to be able to use so that as you watch the patient walk, you have a series of just questions, check boxes that you're checking yes or no that those are there or not there. Just helps to make sure that we're looking at everything. That we're looking at every phase, that we're looking at the ankle, the knee, the hip, and the head arms trunk segment. There was a study done back in 2013 that looked at observational gait analysis tools that are available out there. And for patients with hemiplegia following stroke, they recommended the Gait.

The Gait Assessment Intervention Tool as being the most reliable tool. And they suggested it's use. They recommended its use. This is a great tool. First of all because it makes you look at stance and swing. It makes you look some at what's going on in the upper extremity and the trunk as well. But it just has I think a 30 items on it or so and you're just going to score them like a zero, one, two based on the criteria that's listed there. So it's still somewhat subjective, but you're going to end up with an overall numeric score for the patient. It forces you to look at every joint and it forces you to look at both stance and swing. You can download this online as a PDF. Just you can Google that. It's there. But my point being, there's a lot of these tools. There's some other ones that are listed here. These four are all specific for stroke that are listed here. There are certainly other ones of these observational gait analysis tools for things like pediatric, spinal cord injury, but my point being there are actual tools that would help us do a better observational gait analysis, but many people are not using them. Nobody has put anything in the chat box. So I don't know if that means nobody is doing anything in terms of an actual tool, but I would highly encourage you to get a tool

that you can use. You can get this incorporated into your EMR so that it's in your electronic documentation and you're just scoring it within that. I think that we have to do a better job and be more consistent with our observational gait analysis. I know that sounds like I got on a soap box there, but I'm a little bit on that soap box for sure. We need to examine both of the sub phases. We need to look at that single limb, what's happening there, are they having instability, and do they have impairment in swing limb clearance? We need to make sure that we're assessing both of those, not just looking at what comes easier for us to see which seems to be the swing phase. So as we're looking at the patient and we're assessing their walking and we've done some gait analysis, some observational gait analysis, we then have to come up with what are the impairments that are causing this?

What are the root causes of these deviations that we're seeing? And Perry talked about there being five functional categories. What she talked about was deformity, which we would say range of motion, or some sort of loss of range of motion, muscle weakness, sensory loss, pain, or impaired motor control. And impaired motor control takes us beyond muscle weakness and impaired motor control is about being able to selectively activate.

Do they have any changes in muscle tone either hypo or hyper-tonicity? And so in terms of how we assess that, obviously deformity we measure with range of motion. Goniometric range of motion. And so in walking, well, there's a lot of important range of motions. We need to be able to get dorsiflexion to 10 degrees while the knee is fully extended and we're weightbearing on it, right? So we want to make sure that we're assessing ankle range of motion with the knee fully extended. That's a problem that a lot of times people don't do. Certainly hip extensor range of motion is a big problem in our patients. People who are not very mobile tend to get tight hip flexors. You need to have 20 degrees of hip extension. That's sort of your max capacity for hip extension. So that's another key range of motion that you might want to think about And I'm

getting ahead of myself. So let me get to the next slide before I get any further ahead of myself. We're going to talk about range of motion first, and then we'll work our way through this list. As we're talking about range of motion, I think it's really important to mention the terms R1 and R2. So these terms actually come from a scale for measuring spasticity called the Tardieu scale. I'm not going to go into that, but I do think we all need to consider this idea of R1 and R2. So when I move a limb segment quickly, like let's say, I'm looking at the plantar flexors, so if I move the limb, the ankle into dorsiflexion quickly and I feel an initial resistance, an initial catch, if I stop at that initial catch and I measure that with my goniometer, that's R1 where I feel the initial resistance.

And then I maximally take them into as much dorsiflexion range as I can crank them into and I measure that, that's R2. Their max stretch. And so if R1 and R2 are very far apart, let's say R1 was at minus 10 and R2 is at plus five, that means it's 15 degrees difference there. That suggests that there's some neural component to their loss of range of motion. There's some hyper-tonicity going on there of some type, right? And because I moved them quickly, we would say that was spasticity most likely. If there R1 and R2 are really close together, then we don't have some sort of neural problem going on.

We have more of a musculoskeletal tightness stiffness going on, right? Why is this important? Well, we live and function at our R1. So you may have had patients before that you thought, "Wow, when I give them max stretch, they have really good range of motion, but when they're walking or standing or doing some function, they're not really using their maximum range of motion." Go back and look at where their R1 is because in function our nervous system senses that initial catch and thinks that's the end of the road and says, "Hey, don't go any further because you're about to hurt. This is about to be a big stretch. This is not good. Don't go past this point." And so our nervous system doesn't really allow us to push past our R1 in function. And so that becomes really

important in understanding why a patient moves how they move, but it becomes super important when we think about gait impairments. Things like use of orthotics. That becomes really important to understand what their R1 is. So I don't know if that's new for some of you guys or not, but hopefully you can understand that. And Elena, I'm glad that you use a series of check boxes in the patient's note. That's really good to have something systematic that the same thing's being looked at every time. Excellent. So I kind of jumped ahead in talking about this before. I told you I get so excited. I just can't control my thoughts and my tongue I guess, but how does range of motion loss impact stance and swing most commonly in our patients with stroke?

Well, most every patient that has decreased mobility in the limb or decreased mobility in terms of they're not getting up and walking very much or very well, it's going to end up with plantar flexor tightness. And that's going to greatly disrupt stance. Remember at the end of stance, at terminal stance we need 10 degrees of dorsiflexion. The max dorsiflexion we ever need throughout the body, we need in stance. And so, obviously a plantar flexion contracture is going to disrupt that. And keep in mind that the problem here is the gastroc not the soleus. The soleus doesn't cross the knee. The soleus is rarely ever very tight.

Even if it were tight it would probably not impact stance as much, but that tightness of the gastroc that crosses both the ankle and the knee is going to really impact the stance phase. Hopefully everybody can picture that. Also a knee flexion contracture can greatly impact stance. If the patient can't get that full extension for mid stance and terminal stance, that's going to disrupt stance greatly. And they're going to have to stay with their knee flexed, which is going to mean they're going to have to keep their quadriceps on throughout the stance phase, driving up the energy cost. A knee flexion contracture of something like 15 degrees drives up the energy cost something like 25% or something. It's really quite significant. Much more than that and you're looking at like 50% increase in energy expenditure. And as I mentioned earlier, hip flexion

contracture is very common in our patients who have stroke on their hemiparetic side and oftentimes on their other side as well. They're sitting more, they're not up, they're not moving, they're laying in bed with their head of bed elevated and they're staying in positions that tighten up those hip flexors. If they hip flexors get tight, they can't accomplish push terminal stance. They can't get that 20 degrees of hip extension that's so necessary to help swing then occur normally, right? Range of motion impact that's commonly lost in patients in terms of swing again, plantar flexion contracture is a big contributor here. If my plantar flexors are contracted, I can't even if I have activation in my dorsiflexors, I can't use that to get my foot and ankle to neutral to be able to help with swing phase clearance. So that can greatly disrupt swing phase clearance.

And then obviously a knee flexion contracture is going to limit my ability to get terminal stance. To get that knee extension in terminal stance which is necessary for me to be able to take a really full long step. So range of motion can be a huge problem. A huge disruptor of walking and this occurs really rapidly in our patients with stroke. If we could figure out better ways to improve and to maintain range of motion, we would be in much better shape.

If I could figure out a way to keep patients from losing range of their ankle, I would be very happy and probably consider my life fulfilled there. But so far we don't really have good methods for that unfortunately. We understand that muscle weakness, or really weakness is probably the wrong word. I should put there insufficient recruitment or insufficient activation because when a person acutely has a stroke, they don't actually have weakness, right? Their muscle fibers are all the same. They haven't lost or atrophied any muscles, but they've lost the ability to recruit and activate. So we understand that I think a lot better, but one thing to keep in mind is that when we're assessing our patient, it's really about more than the manual muscle test grade, right? So first of all, a couple of things about manual muscle testing. In our patients with

stroke especially early on, it's not very accurate because oftentimes they can't volitionally recruit, but in a functional task they may be able to recruit. So just saying, "Straighten your knee, or lift your toes up off the floor." They may not be able to do that, but in function they may be able to activate those muscles. So it's hard to get a really good picture of their muscle activation with MMT. As they progress and they maybe develop some hyper-tonicity, it becomes hard to get a good MMT measure because it's hard to know, are they volitionally moving or are they utilizing some hyper-tonicity here to help with the movement? So manual muscle testing is tricky in our patients with stroke. The other thing I would encourage us to look beyond just the strength grade, to look at endurance.

Many of our patients can get what I call a one repetition wonder. They can get a four or a five maybe in a muscle group, but then when you watch them walk, you're like, "Wow, they had such a good muscle score, but when I watched them walk, it looks like they're not really using that very well." Could be a muscle endurance issue. So you might want to think about, you do your MMT of the muscle and then maybe you have them do 20 repetitions of just the active movement and you retest that muscle and see now are they able to hold with the same resistance?

If they're not, then they have some muscle endurance issue. And we want to think about that. The other thing I want to think about is lever length. So we are testing them in sort of their mid range position and where we function especially in standing and walking is a lot of in-range positions. And so being able to have a normal strong contraction throughout the range of motion is important. And our patients with stroke typically don't get a good contraction when they're in the shortened position and in some ways also when they're in the fully lengthened position. So we want to make sure we're considering the length of the lever as well. Not just can they get a good contraction in that nice mid range position we learned to do for manual muscle test. The other thing I would throw in there is power and the need to develop speed with our

activation. And we'll talk about that a little bit more in a second. So, some normal muscle activity in gait and then how that's impacted in stance. We kind of have already talked through this, but this is just a reminder. And initial contact and loading response, that's really heavy on the glutes and the quads. And they peak by the end of loading response and then they start to turn off. Muscle activity in mid to terminal stance: That's the glutes and the quads just for a very short period of time or maybe no time early on in mid stance.

But then most of mid stance to terminal stance is managed by the plantar flexors. And it's the highest torque demand that we see. So when you think about it, when I'm in 10 degrees dorsiflexion, that's a very high torque demand for my plantar flexors to be controlling. And you think about, they're controlling a very long lever arm. The total height of the patient essentially they're controlling. So think about your patient's body weight and height. That's what your plantar flexors were holding back with each step.

So really huge amount of torque that has to be developed by the plantar flexors. How many of you have patients who seem to have plantar flexors which work very well? I'm guessing that you probably all are saying not so much, right? And we know that plantar flexor weakness is really huge in our patients with stroke. Tends not to recover. Maybe it doesn't recover 'cause we don't do some things to recover it well. I'm just gonna throw that out there and then we'll talk about it some more as we move forward. So muscle weakness in stance again, I said this earlier. So this is being a bit redundant. When they have quadriceps weakness, you'll see that hyperextension, really early initial contact or early loading response. And they'll just stay hyper-extended versus when they have plantar flexor weakness or plantar flexor weakness is the bigger weakness I should say. They'll have that extensor thrust in mid to terminal stance, or they'll just keep that crouch position. When they have hip extensor weakness, they're going to have excessive hip flexion at initial contact and loading response and they're also gonna really rely on their upper extremities on an assistive device. When they have hip

abductor weakness, they'll have that contralateral pelvic drop or Trendelenburg that we're familiar with in mid stance. When they have anterior tibialis weakness in terms of stance, they'll have that foot slap at loading response that you can actually hear or you can see as well, but you can hear that when you're there with them. And so I just remind you that plantar flexor weakness in stance can present two different ways, right? Those two gentlemen that we talked about, we can see both of those ways. So to kind of sum up a little bit more about stance, it's so much more than just decreased weight shift. And that's what I see a lot of people they'll document. They have decreased weight shift to the affected side. It's less time on the paretic limb. It's reduced load on the paretic limb. It's going to make the non-paretic limb take a much shorter step. And again, in both acute and chronic phase of stroke, weakness of the plantar flexors is really most common in terms of the primary impairment that we see in stance. In the chronic phase you're really splitting between weakness of the plantar flexors along with a contracture or hyper-tonicity of the plantar flexors.

And as I said earlier, often not identified, described or addressed. Muscle weakness in swing, we can identify this really easily. We can tick these things off. This is anterior tibialis weakness. That's the one that we sort of latched onto the quickest, right? Their toes or I always say their toes are pointed south in swing when they should be pointing straight ahead. And we go, "Oh, the anterior tibialis is weak." That's true. They'll make a flat foot contact or forefoot contact. And then they'll have decreased foot clearance throughout swing. But knee flexor weakness can contribute to some swing issues, but just remember that the knee flexors don't actively work in swing until initial swing. Pre-swing into initial swing is all passive, then the knee flexors come on, the hamstrings come on through mid swing to help complete that flexion that needs to take place. At the end of all that flexion, then the knee has to extend again. The quadriceps have to come on to get that full terminal swing. But one of the big contributors that I feel like is often overlooked is the hip flexor weakness. Yes, dorsiflexors stand out to us and certainly their toes dragging the ground is problematic.

But the hip flexor weakness is causing the entire limb to drag. The hip flexor weakness and the hip flexor's inability to generate power, meaning activation with speed, that really impacts swing very, very dramatically. So they'll have difficulty initiating pre-swing and initial swing. And they may have some internal or external rotation of the limb because they have a lack of imbalance amongst the flexors. And all of those are going to add up to just poor limb clearance.

So if we can go back and watch the video three now. So, we could have watched those other two people without any issue. I'm sorry I was about to click. We could have watched those other two people and identified their swing problem. I chose this woman 'cause we have her from the front. So here you can see some of the classic swing problems, right? We're not beside her, but we can definitely tell she's not getting 60 degrees of knee flexion. That's what you should get total in swing. She's definitely not getting 60 degrees of knee flexion and that's causing her then to have to circumduct and somewhat hip hike and push her trunk the other direction too far to the left, right? To be able to accomplish swing.

You can see that she has excessive plantar flexion throughout swing phase, right? So that's the easy thing for us to see. That she doesn't keep that foot at neutral. But the other things to really key in on is that she does not get the normal knee flexion, she does not get the normal hip flexion. She doesn't get the momentum generation of that swing limb that she should be getting. Part of swing limb clearance is via momentum and she definitely doesn't look like she's generating any momentum. So, that was just a highlight of some of the swing phase issues. And we can go back to the slides. So we talked about range of motion, we talked about muscle activity. I want to also talk about impaired motor control. So because our patients have an upper motor neuron lesion when they've had a stroke, we would expect them to have some significant problems with motor control. And so this is going to be beyond just muscle weakness. This is going to be an inability to selectively activate and control, right? So our patients

oftentimes have some dorsiflexor activation a little bit, but when they try to fire their dorsiflexors, they don't have selective activation of their dorsiflexors. They actually fire several muscles at the same time and they typically fire the dorsiflexors and their plantar flexors at the same time. And if you can imagine, if you could look inside your body at your anterior tibialis versus your gastroc, you can imagine which one of those muscles is going to win that race, right? Your gastroc is huge compared to your tibia anterior. And so when you don't have that normal selective control, then you have sort of the larger more active muscles that are overtaking the movements and not allowing those smaller muscles to fire even if they have the capacity to. Or to win I guess we should say.

And because of that you develop some synergistic patterns, right? The woman before us, we would look at her and we'd say, "She looks like she has some extensor synergistic pattern in her lower extremity as she's walking." And certainly that may well be the case. And certainly if a person has some type of hypertonicity, whether it's spasticity, dystonia or rigidity, that's going to contribute to problems here as well. So we want to make sure that we're assessing that and taking that into account. But I will say that remember the hypertonicity by itself is just resistance to passive movement.

And that's made up of a muscular component. So the stiffness of the muscle plus that neural component. And sometimes we sort of underestimate or discount that stiffness of the muscle component. All of our patients that are especially in the chronic phase may have some hypertonicity. They may have some neural component, but they're also going to have a great degree of stiffness of the tissues. The muscle, the neurovascular bundle, stiffness of the actual joint and capsule itself. And important to keep that in mind and address that. So in coming back to our examination, so we've done our observational gait analysis, we've looked at all the impairments that could be contributing, I want to talk just a little bit about objective outcome measures. So we definitely want to look at speed. It's referred to as the sixth vital sign. Super important.

Correlates with all kinds of other functional outcomes. It's a predictor of discharge. Placement, future hospitalizations, all kinds of things. So really important to get a measure of speed. Really important to get a measure of endurance. The six minute walk test or some measure of endurance correlates really strongly with their ability to return to community mobility. So when we're trying to be able to figure out or justify potentially why the patient needs more therapy, looking at the six minute walk tests and knowing that it correlates strongly with their ability to return to the community is important, right? So we can do endurance with the two, six or 12 minute walk. The six minute walk is probably the more commonly chosen one. The six minute walk also correlates well with overall fitness.

So we can't get all of our patients doing some type of VO2max tasks where they're wearing, have a metabolic cart and they're wearing the mask and doing something on the treadmill. That doesn't happen to many of my patients. I don't know about yours. But the six minute walk test correlates really strongly with those. So that's another good reason to do endurance or to do the six minute walk test. We also want to look at a combination of gait and balance measures. So I've listed there sort of in the Timed Up and Go. It's just a good generic.

Always good to do measure the Berg, the Dynamic Gait Index and the Functional Gait Assessment. That's kind of listed in order of progression from less dynamic to most dynamic. And we want to make sure we're matching up our outcome measure with the patient, right? If the patient is really highly functioning and out in the community doing stuff, we probably don't want to do the Berg Balance Test 'cause they're going to score really well. We want to choose something that's a little bit more challenging like the Functional Gait Assessment. My suggestion would be that you choose one measure from each of these categories and you do a trifecta of outcome measures where you're looking at speed, you're looking at endurance, and you're looking at some measure of balance. I think that's going to give you the best objective picture about your patient

when you combine that with your good observational gait analysis. We need to be looking at some measure of participation. Some measure of quality of life, life satisfaction. We know that life satisfaction improves. Quality of life improves when walking improves, but this is a measure that we rarely include in our objective assessment. We also should probably look at the link to cost and caregiver burden. Are we making caregiver burden less when we are improving their walking function? Certainly that's something that's important following stroke. So let's shift to talk about interventions. So in 2016 there was a paper published about outcome measures. Not outcome measures. Sorry. I got that on my brain now. That was essentially a clinical practice guideline.

Best practice guideline for managing adults with stroke. This was published in the Journal of Stroke in 2016 with Kelly Weinstein as the lead article and lots of other really smart people across the world contributed to this. And it's really a long paper. I'm certainly not going to go into all of it with you, but I'm going to kind of summarize just a little bit of their most recommended interventions based on the evidence. And the very top one, and I think they're listed kind of in order, but all of these were strongly recommended or I should say they had strong evidence support. And the very top one is intensive, repetitive, mobility task training, right?

What we have been talking about now for the past several years that we have to look at making things intensive, novel so that there's motor learning that's involved in their, task-specific and highly repetitious, right? So, first order of business there. They found strong evidence for the use of an AFO in patients who had what they defined as remediable gait impairments i.e. if patients had a gait impairment that could be improved with an AFO, you should use an AFO. They found circuit training to have strong support. They found lots of evidence for incorporating cardiovascular exercise and strengthening. In NMES, they found strong support. Treadmill and overground training with and without body weight support. Those just again, I didn't hit all of the

ones, but those were kind of their top recommendations based on the evidence. And we're going to go into a little bit more detail about some of these. So the first thing I want to say is if you look at this list, I think in this list, they're targeting several areas, right? And that really kind of sums up this paper, which is a little bit old at this point I guess now that we're in 2020. It was in 2011, but this is a great paper about optimizing walking following stroke. And I always think about this is what they're telling us to do is rehabilitate all the components. We need to look at walking-specific motor control. So which means we need to be doing task-specific repetitive step training, right? Whether we do it with or without body weight support, body weight support is a means to an end. It's a tool to use until I don't need that tool anymore.

If I can already get my patient doing highly repetitious walking without body weight support, then I don't need to use that tool. But we need to be doing that task training. We need to be doing that repetitive step practice. We need to be working on them getting better selective control at a lower extremity while they're walking. We have to be doing cardio-respiratory fitness. It takes a significant amount of cardio-respiratory fitness to walk.

So we need to be doing aerobic conditioning. It doesn't have to be gait-specific. We could do this in some other means that's strengthening their cardiovascular system, right? We need to be training dynamic balance. You might think, well, as they're walking, their balance is just going to get better. No, no it doesn't. And a matter of fact, if all I'm focusing on is walking and I'm just getting the patient walking more and they're maybe walking faster and walking more, but their balance is not getting any better, I've actually made them a bigger fall risk, right? I've actually made them a higher fall risk by making them a better walker, but not giving them the balance capacity for that. So if we're improving walking capacity, we want to be improving their dynamic balance capacity at the same rate. That's going to decrease their fall risk versus increasing their fall risk. So we need to have a really good progressive balance program

that looks at all of the components of balance: The vestibular, the vision, and some amount of sensory that looks at things like reactive and anticipatory balance responses, right? That's going along with this. And then we want to look at muscle strength and power. We need to do some progressive resistance training. And we're going to talk a little bit later about the specifics of that. We need to strengthen the paretic and the non-paretic side. So oftentimes we're just focusing on the paretic, but the non-paretic side is weak as well. Weak from the stroke and mostly weak from inactivity in mobility that follows the stroke, right? And we want to make our strengthening as task-specific as possible.

And we're going to talk about this in a second. But I'll sum this slide up to say this, if what we want to improve is walking function, but all we ever do is walk the patient, walk with the patient, we're not really going to improve their overall functional walking. We might make them walk a little bit further or faster or something more. We're not going to really improve their overall walking unless we're rehabilitating all of these components. So strength training I put some evidence that's here. This has been something that's been very debated. There's evidence that it does improve walking, there's some evidence that it doesn't. That doesn't really transfer strength gains. So they really transfer the function.

And what we know is the training needs to be specific. We need to be training specifically to the way the muscle is used in gait. And we'll talk about that in a second. But there is fair to strong evidence that supports that strength gains can impact gait and as well as that they don't improve, I mean that they don't increase spasticity. There was for a long time this idea that strengthening would increase spasticity, and that's just not true. Not founded at all. And analyze their walking, right? Which we've talked about how to do. I need to hypothesize those potential impairments that are causing the problem. And then I need to look at how are those specific impairments impacting walking? So in terms of, if we think about strengthening, which is what we're talking

about here, I want to think about how is that muscle group normally used in walking in that phase? What was the amount of motor activity? Is it something that's high endurance or high resistance, high speed? Is it what range of motion is that muscle being used in? I want to think about what's the type of contraction? Is it something concentric, eccentric or isometric which I mentioned earlier? And when we talked about the quadriceps in loading response, that they're acting eccentrically. The anterior tibialis and loading response is acting eccentrically. If I'm trying to treat either one of those issues in walking, I need to make sure I'm doing activities that are eccentric, right? To be task-specific. We want to think about the specific range of motion that they're used in.

And we want to think about training to fit the demand of the load that's occurring in walking, the amount of repetition that's necessary, and the lever arm that's necessary. So if in walking I'm doing something that's a very long lever activity like what the plantar flexors are doing, I have to think about how do I train the plantar flexors in such a long lever way? So the example that I wanted to use is about how do we typically strengthen the plantar flexors? So, oftentimes we do what's here on the left. We just have the person do heel raises.

And certainly this is going to strengthen their plantar flexors. Absolutely going to hypertrophy their plantar flexors if they have activation, but this is kind of the opposite of how the plantar flexors are used in walking. This is a primarily concentric activity. There is some eccentric lowering back down, but they're going from neutral position at the ankle to plantar flexion versus in walking I'm going from plantar flexion into dorsiflexion, right? So you can see there's a range of motion mismatch here. There's a little bit of a muscle activity mismatch here. There's really also very little torque demand in this position. They're pushing their body straight up as opposed to in walking my body is forward. My center of mass is out over my toes creating a really high torque demand at the ankle. So that's really missing in this particular type of activity. Going to

make the muscle stronger, but is this going to contribute to walking? Maybe not. Sometimes we have people strengthened by standing on a step. And so we'll have them do a heel raise, but then lower down into a dorsiflexed position. It's also great for stretching, right? Highly recommend this for stretching. And this is maybe a little bit more task-specific because they at least are going into a dorsiflexion position, but again, it's kind of the wrong direction. They're going from dorsiflexion into plantar flexion, back to dorsiflexion. Not quite in the same order as they do with walking. And again, it's a lot of concentric and less eccentric, and it's also straight up and down with less torque demand here at the ankle unless they're actually leaning their body forward more. So that's how we would normally train. What are some ways that we can do this more task-specifically?

I'm going to show you a couple of examples and if we can go to the video, the next one, there's nothing magic about these particular exercises. I just wanted to be able to demonstrate some ways that get more at that eccentric control of the plantar flexors. So in this, this is one of my students who was volunteering for the video. I've given some targets on the wall. Some things for her to reach. It was kind of boring task, but, and the cue is to stay standing.

Not stick her bottom out. Keep herself in nice alignment and to just progressively reach forward for the targets that are on the wall. So you can see here at this point, she's sort of in a mid stance position. And as she goes forward, you can see now she's in more of a terminal stance position. And every time she takes her hand away from the wall, she's having to hold herself with those plantar flexors, right? Or better yet, she's having to eccentrically allow her center of mass to go a little bit further forward using her plantar flexors. Now, obviously for my patient, this would be... And she's showing the end position she was in there just for the video. For my patient, I'd be there guarding them. I would maybe do some things to bias them towards their more affected side, but you can see there that this is getting more at how the plantar flexors are actually

used in walking versus doing heel raises, right? And that's all that's about. It's just giving you a different way to think about it. If I can show the next video, again, this is just the student being the model here, but this was based on a patient that we had who was a basketball player and he would do anything if you gave him a basketball, but there had to be basketball somehow involved.

And so we put targets up on the wall for him. He was very tall and we had him with the basketball try to touch progressively high targets, but he would touch them and then pull the ball away just a little bit and then have to touch progressively higher, or keep touching the ball to the wall, not just leaning into the wall. And as you can see, we have to make sure that we have her started where her feet are far enough back from the wall to be a challenge, but as she progressively takes that ball away from the wall and pushes it up higher and higher, she has to control her center of mass with her plantar flexors or she'd fall forward into the wall, right? And again, nothing magic about these particular exercises.

I can do this at a functional task standing in somebody's kitchen, having them put away the dishes or something, but I'm just thinking about that I'm putting them in a position that's going to stress those plantar flexors and get them activating. We can go back to the slides. A couple of other suggestions I have for sort of task-specific training of the plantar flexors is to utilize their balance reactions. And I didn't put pictures of this in here, but I will throw this in 'cause I think this is important. Having the patient stand and resist some gentle perturbations forwards and backwards, will get them to elicit a very automatic balance response that utilizes their plantar flexors and their dorsiflexors. And that can be a way to start automatically getting activation in the plantar flexors utilizing balance strategy. So anything that you can do that's going to get those normal ankle strategy responses will be a way to get those plantar flexors firing. So back to a little bit more of the evidence that we talked about, that was kinda talking about strengthening, how it needs to be task-specific, there's lots of stuff out there about

body weight support system training. And I will tell you that sometimes I feel like, I don't know how you guys feel, but I think this is confusing 'cause there's some evidence that strongly supports the use of body weight support, some evidence that says not so much. At the bottom line, and you'll see this in one of the papers I present at the end here, the bottom line is there's pretty significant evidence that supports the use of body weight support. I think there's still so many questions that we don't know the answers to. Like, what's the optimal dose? How do we best progress people? Who responds best, right?

Who are the people that really need to be using this versus who don't need to be using this? And when is this intervention best used? I would suggest that one of the things that I think is a strong possibility is that body weight support is probably best utilized early when patients don't necessarily have the capacity to be walking very much, very far, very fast on their own. And this allows them to get in more of that high intensity repetition that we know is so essential, right? I think definitely those patients can benefit from this. And one bit of evidence that I didn't put in here, but I definitely want to give mention too here is some work by Karen McCain at UT Southwestern here in Texas, who's done some work looking at patients with stroke very early on using body weight support treadmill training.

She gets them within the first, I think four weeks of stroke. She hopes to recruit them before they've actually started any significant amount of walking. And she doesn't have them walk over ground. Just allow them to walk over ground until they can walk a certain distance at a certain speed with a certain amount of body weight support on the treadmill. So she starts them off in treadmill training with a very detailed, progressive way of decreasing their body weight support and decreasing their assists. They wear an AFO to substitute for dorsiflexors and plantar flexors if they need that until they don't need it, but she progresses them on the treadmill. And once they reach sort of a predetermined level of walking, then she starts walking them over ground. The

idea being that she's not allowing them to develop those abnormal patterns that the body weight support and the assistance provided via the therapist and via the orthosis prevents them from having to develop those patterns that we saw in those other videos. And she has some outstanding results with patients who not only walk well, but walk with much more normal kinematics and kinetics. So more normal joint angles as well as muscle activity compared to what we would typically see. And many of them walk out of meeting their AFO and no longer need their AFO as well.

So that's Karen McCain. If you have any interest in reading more, I could get you those papers, but her work always reminds me that A, early intervention is really important, and B, we want to try to do what we can to minimize the development of those typical patterns that we see in our patients with stroke. There's lots of evidence coming forward about high intensity dynamic stepping. This was a paper from back in 2016. They looked at high intensity stepping practice in variable environments. So they did things like stepping forward, stepping backwards, stepping over obstacles. They did this on the treadmill.

They did this overground. They walked at varying speeds. They kept them at a pretty high heart rate. You can see they're 70 to 80% of heart rate reserve. They would weight them. They would tie them with thigh band that would then give them perturbation various directions. So this was a very well responded to study. They found significant improvements in not only walking function, but things related to overall physical fitness VO2max and O2-cost and those kinds of things improved as well as all the walking function improved. So this idea that we need to be introducing a great deal of variability and intensity into our walking recovery. Circuit training was mentioned in the paper that I cited at the very beginning of talking about interventions. And I've given you just several slides that go over the evidence of circuit training. But circuit training is a great way to get at that rehabilitating all the parts. You can develop a walking circuit where they have 10 minutes of something that's relatively cardiovascular. 10 minutes of

something that's relatively balance-related, 10 minutes of something that's relatively strengthening, 10 minutes of something that's more related to motor control. Selective activation kinds of activities. That's something that you can utilize a small group of patients. You can utilize less skilled supervision of these folks. So it has a lot of benefits. So I provided you with several papers that have talked about that. But again, all the evidence here suggests that not only do things like walking speed and endurance improve, but balance and other outcomes improve as well. So I wanted to make sure that I included that. Again this is a paper from 2015 about variable intensive early walking training.

And again, this looked at not only the importance of that degree of variability, they did things again where they did lots of changing in speed. They did things where it required different skill for treadmill walking such as stepping over obstacles, resisting those perturbations that we talked about before. They did a similar protocol to what we talked about before. Excuse me. Sorry. And they did them in short 10 minute bouts. So they would do 10 minute bouts of each sort of category of walking. Again increasing the variability in the protocol. They weren't doing the same thing for a long period of time.

And the way that they challenged them was they had a very set way of progressing difficulty. Sorry, that's a typo. That should say difficulty was progressed. They had a standardized way of progressing difficulty and they only decreased difficulty when the participant was not successful for three to five consecutive stepping attempts. So when they got to the point that they had several steps that they were not being successful at, then they would back off the intensity. But they were really pushing the intensity. And what they found here is that not only were there improvements in speed, but there were improvements in distance, there were improvements in the overall stepping amount that that folks did throughout the day. And that all of these improvements were related to the degree of intensity that the patient was practicing at.

There were improvements in their temporal gait. So looking at things, all the timing related things. And then the other thing that I wanted to make sure I mentioned about this paper is there were improvements in self-reported participation. So patients reported having higher participation. That's really where the rubber meets the road, right? Is what we're doing actually changing and improving the patient's participation? So again, emphasis on high intensity and lots of variability. And there's been several papers that fall under that same idea. I just pulled out a few of the best ones I thought, but you can look up that topic of variable and intensive walking and you'll find lots of different papers out there. All very suggestive of the positive findings of variability and intensity.

This is a paper that was just published this year that I wanted to bring to your attention. It's called "A Biomechanics-Driven Exercise Prescription." And this paper caught my eye. Actually I was a reviewer for this paper before it went to print, and I was really excited about it. They looked at walking from a biomechanics standpoint and they found that the most important muscle groups for forward propulsion aren't typically the ones that we target for strengthening. And again, they highlighted the importance of the plantar flexors in that.

And so they highlighted a key sort of deficit I thought in what we're doing, and then they also talked about that our strengthening typically focuses on slow and heavy resistance. It doesn't really look at those fast muscle contractions that are needed for walking. We do a lot of slow and heavy resistance and then we wonder why we're not seeing an improvement in fast muscle contractions which are needed for walking. And what they propose as a solution to this is that we do strength training with resistance exercises that target power generation. That we're looking at things that are more plyometric and ballistic in nature in terms of our resistance exercise. So doing things like plyometrics on a rebounder, doing things like a total gym like kind of exercise and focusing our intervention or exercise intervention on things that target speed which are

going to help us develop power. And I will tell you there was an interesting little case series that was published a while back and I can't cite the source, I'm sorry. And it wasn't specific in stroke, but to me it really resonated just with what I need to be doing with all of my patients in terms of improving walking. This was actually done in some folks. Some adults with CP and they looked at training the quadriceps, strengthening the quadriceps, and they had two groups: One that they strengthened at like a self-selected or kind of a slow speed of quadriceps exercise. And then they had another group that they strengthened at multiple speeds.

So there were using equipment where they could control the speed of activation through the long arc quad kind of movement. And both groups improved in quadriceps strength, right? Both groups got better. Not surprising. What groups got faster with walking? The group that trained at the variable speed. That trained at higher speeds of quadriceps activity. And so to me that was very enlightening. I was like, okay, we always talk about our patients need to be faster. Walking is a relatively fast activity, but we're not really training our patients in terms of our strengthening exercises to be able to generate that.

Hip flexors really move very, very fast in terms of walking. And when you work more on power as well as just strength in the hip flexors, you'll find that your patient's swing phase improves much more dramatically when you focus on that speed component. It was really the same with all the strengthening. Need to focus on that speed component. Definitely with the plantar flexors, A, we need to be focusing on them more because they are what are contributing to our forward propulsion most, but we need to be focusing on the speed component of that as well. Maybe getting away from the slow and heavy resistance to more of the fast, higher endurance kinds of stuff. So the last piece of evidence that I wanted to talk about related to just kind of overall walking was this study that just came out. This clinical practice guideline that just came out this year on locomotor function. So this doesn't look just at patients with stroke. It's

actually several neurological diagnoses, stroke, brain injury, spinal cord injury. And again, it's a really long paper. I would encourage you to go look at it. I just kind of tried to summarize here to kind of cap off talking about this evidence. They found strong evidence for several interventions. They really had to do a training at moderate to high intensity. Is not surprising, right? They also found strong evidence for utilizing virtual reality-based training. And I know that's something that many of us don't have access to, but probably in the future that we will. They didn't find very good evidence for strength training, circuit training, which the previous paper that I suggested or that I cited did. So, I mean, I'm not saying that one is right and one is wrong, I think we need to look at all of them together. They found evidence, but not as strong of evidence for strength training, circuit training, cycle training.

But again, the question is, were they at sufficient intensities to be able to promote the changes in walking that they wanted to be able to see? There was strong evidence for body weight support treadmill training. More for a manual assisted as opposed to robotic assisted. But again, this idea that virtual reality seemed to improve outcomes with all of these types of measures. But yeah, so the good news there being that there is significant evidence supporting various interventions for walking. The bad news is that we really have to get better at our intensity of walking training. Looking at more moderate to high intensities.

And then the last thing that I wanted to include here, it's just a couple words on... Not a couple of words. A few words on a FES and orthotics. So I get asked a lot about the use of FES for patients with stroke. Something like a walk aid or a bioness. And the issue here is that an FES really only provides dorsiflexion assist in swing. It doesn't really address the stance phase issue. So in persons with stroke, they really don't have an isolated foot drop problem, right? They don't have just weakness of the anterior tibialis, they have problems in swing related to weakness of the anterior tibialis, but also related to weakness in the knee flexors and the hip flexors. And then they also

have significant stance phase problems. And FES can't address stance phase problems. They may try to tell you that it can, but really bio-mechanically, physiologically it really can't. I put in here, I'm not going to go through this. I just put this for reference. There's significant evidence that shows FES improves walking when compared to nothing. So when you compare an FES device to no device, definitely better with walking. And that makes sense. When you compare FES to AFO, there's been some mixed results. This study in 2015, the results were that FES proved non-inferior. So not better, not worse of two AFOs in all measures. There's some evidence that suggests that people may like FES better than an AFO. That there may be a preference of patients for FES over an AFO. But this study in 2011 talked about different experiences of both tools led to frequent choices to supplement FES with different types of AFOs.

I'm not really sure that supplementing FES, which is a very expensive intervention with an AFO, which is also an expensive intervention, I feel like we probably should not be prescribing or utilizing both of them, right? When an AFO can do the work of both the FES and the AFO. I think we probably should choose wisely there in terms of the money that's involved. But that's just the evidence that's found. Yes, there tends to be a preference, but when you actually get down to it, patients ended up having to supplement their FES with AFOs.

And so I can sum up the idea there about use of FES by just going back to what I said at the beginning. Our gait problems after stroke are not just confined to the anterior tibia weakness. We have a significant stance problem. FES can't adequately address the stance problem. If they have both a swing problem and a stance problem, then they're going to need something beyond FES just to sum that up. And again, that's a topic that could be a much bigger topic, but I wanted to make sure that I included a little commentary here about that. And then lastly, we'll talk about orthotics and assistive devices. So again, I gave you just a summary of evidence here mostly to

prove there's a lot of evidence because I feel like oftentimes people think that there's not a lot of supportive evidence about orthotics and a gait related to stroke. And there's actually as you can see a ton of evidence there, all supportive that orthotics improved gait in terms of quality of gait, gait speed, reduced energy expenditure, very immediate improvements in walking when you use an orthotic device, immediate improvements in gait speed, quality and endurance, that they increase step and stride link. So the temporal and spatial parameters of walking improve. Improvements in balance, decrease in fall risk. Not actually detrimental to stair climbing and sit to stand which is something we oftentimes hear that if you give them an AFO, they're not gonna be able to do stair climbing or they'll have difficulty with sit to stand. There was less postural sway and improved weight distribution. More symmetry in weight distribution with the use of AFO.

There's no data on impact of quality of life or participation, but really all the factors related to gait and balance did seem to improve with orthotic use. At least that's what we see in the evidence. And I should preface all this by saying there could be a whole course on orthotics as well, right? And I'm just going to touch on it in just a few minutes here. But a few really important things in thinking about orthotic management with our patients with stroke. Most of our patients as I said have a loss of range of motion at the ankle. And we have to remember that. And we have to accommodate that loss range of motion or that hypertonicity at the ankle. So the first thing to remember is R1 and R2.

And so if their R2 is at minus five and we put them in a device that's trying to hold them at plus five, there that's not gonna work. They're going to constantly break down. They're constantly going to be pushing out of their device. It's not going to hold them. They're going to be getting red. They're going to have significant issues there. So we have to think about bracing them where their R1 is. We have to think about if they have a plantar flexion contracture, we are going to have to accommodate that with some

type of heel wedge. We have to remember that when we're suggesting use of orthotics, we need to make sure we're measuring their range of motion at their ankle with their knee extended, remembering that the gastroc has two joint muscle and crosses the knee, right? There's no set guidelines to tell us which type of device is best with which patient, but I can tell you that you can fix just about any problem in terms of at the ankle in swing with just about any device. This device here, let me get my pointer. This device here on the left, it's definitely a device that we could use that would fix their swing problem in terms of at the ankle. However, this does nothing to help them with stance. This is a posterior leaf spring. Very, very thin plastic at the back here. A very narrow strip of plastic. When the patient comes into stance, it will just dorsiflex. It'll just bend. It's very flexible.

So it's only supposed to help them in the swing phase, right? So don't give this to your patient who has stance phase problems that has plantar flexor weakness. If the patient has plantar flexor weakness, we need a device that provides sufficient stiffness to substitute for the plantar flexors. So we need a device that's solid. Potentially solid that would be one solution, but even a solid device isn't as solid as you think.

Depending on the thickness of the plastic that's here, when it's made out of this polypropylene plastic, if you can imagine loading this device with a 180 pound person that's six foot tall, when they lean into this device, you'll see that it kinda gaps here at the ankle. It kind of bows out. That's not really solid, right? It's not really completely resisting motion. It's giving some just by the tensile strength of the materials that it's made of. We can choose to give somebody an articulated device that's got a joint in it. It's going to allow them movement. My advice here is only give them that movement if they have the plantar flexor capacity to handle that movement. If I'm giving them this movement and their plantar flexors are weak: Zero, one, two, maybe even three, they're never going to actually use this range of motion that I've given them, they're going to still walk with that knee center thrust kind of pattern because they need

something to resist that forward motion and this does not give them any resistance, right? There are certainly devices. You can use a strap back here on the back. A dorsiflexion restraint strap and that can maybe resist that forward motion thumb. But again, you got to think about the high degree of torque demand on the plantar flexors that's occurring down here at the ankle and what what's gonna provide sufficient stiffness to substitute for a muscle which controls my body weight each step that I take. Neural materials, something like a carbon fiber stretch which is what this device is. This is a ground reaction device. Meaning instead of coming in from the front, where the panel is posterior here, the panel is anterior here. So that's what makes it a ground reaction. And this is a carbon fiber strut. We're getting to a point where we can engineer technology.

That we can use a variety of carbon fiber struts that give us a variety of stiffness and can potentially change with the patient. But in this device as this person loads this device, this carbon fiber strut is going to give significant resistance to forward motion. And it's only gonna allow a tiny bit of forward motion. Almost imperceptible to us, but enough that it mimics what the plantar flexors would do. So this is much more adequately gonna control depending on the strut that's used here and the patient that's in it. This is much more adequately going to apply stiffness similar to what the plantar flexors would apply in walking.

So we need to think about what's the weakness of the plantar flexors and choose the appropriate stiffness to substitute for that. And we'll talk a little bit more about orthotics just in a second, but I also want to say a quick word about assistive devices. You can totally change your patient's walking pattern by the type of assistive device that you give them, right? In acute care, our patients with stroke may need something super supportive like this. Like a platform walker. This is certainly not functional to take home necessarily, but they may need this amount of support to be up and be walking and to get more repetitions. And if that's what they need, I'm all for it. I don't know if it's going

to allow them to walk with a more normal pattern and go further and maybe be able to go faster. So think about that. Sometimes we think, "Oh, I'm going to choose something less supportive." Which I am also an advocate for at the right time, but if that's disallowing them from getting in that intensity, we may want to provide something that gives them a little bit more support. The benefits of something that is a walker and a rolling walker of some sort is that it keeps them moving, right? It allows for more continuous stepping, whereas when we give them a single point device like a cane or a quad cane which is a four-point device or a hemi walker, that disallows kind of continuous stepping, especially the quad cane and the hemi walker, 'cause they have to pause, pick that up, and move it kind of thing in order to use it correctly. A hemi walker is a particularly poor device for our patients with stroke because it promotes them way overusing their strong side.

This device essentially says, "Lean on your strong side and just let it all be over here on your strong side." It gives them too much support and they overuse this and they become a person that literally walks leaning to whichever side, right? Because they have just learned to lean into that device. A Y-based quad cane again can almost do the same sort of thing. So we want to think about, I always hear patients say, "Well, they've had a stroke.

Let's give them a quad cane." Well, there's no prescriptiveness, right? And so we don't want to give them a device that is too much for them. That's providing them too much support. And the last thing I want to say is I try to progress my patients to a single-point device. And I utilize a walking stick quite often for some of my patients especially my taller folks. Tends to help keep them more upright. Some of my folks find it more aesthetically pleasing than a cane. And so that's a device that we should probably think about using more than we do. So I put in here some summary thoughts. We really want to look at normalizing the biomechanics, controlling or limiting the degrees of freedom so they don't to struggle so much to move so that they can move a

little bit more easily. And then orthosis is definitely a way that we can help with that. Think about anticipating problems. Avoiding those overuse injuries that are coming kind of thing. Understanding that we don't see recovery just automatically happen in the distal musculature. We have to go after that by being task-specific in our training. Really trying to facilitate walking capacity without abnormal patterns. Making walking more automatic. Stop telling your patient to think about their walking and do some things to make it more automatic. Do some things to help match their demand to capacity. So in other words, don't make walking so challenging that they can't rise to that. We talked about task-specific training and task-specific practice as well. Find ways to increase speed and create opportunities for motor learning. So what are ways that we can create opportunities for learning in the task?

Don't forget things like dual tasking. Don't forget things that make walking much more variable in high intensity. And walking is way more than walking forward. We should be training our patients in walking sideways, sidestepping, backwards walking. I feel like a lot of people fall in the bathroom, opening doorways. And those all involve stepping backwards. Stepping backwards sometimes in the case of the doorway, they're actually pulling something towards them and stepping backwards, right? So we need to be training more than just walking forward. And I feel like way too often we just have the patient walking forward. So then the last thing I'd like to do in the time that's remaining is to look at this particular case study. This person is a 60 year old male who had a hemorrhagic stroke that left him with Right hemiplegia. We're going to watch a video and look at his gait deviations. And so actually let's go ahead and go to that last video there. Not the last one but the next one. Sorry. Oh, yeah. So this is him walking without any sort of orthosis and you can see that. So he has Right hemiplegia. Kind of looks like that first gentleman we looked at. He's a bit of a croucher. He tends to stay in too much flexion at the ankle, too much flexion at the knee, too much flexion at the hip. And then he has to keep the other knee flexed as well. So we definitely have some significant stance instability. If we look at swing, he has a little bit of active dorsiflexion,

but not normal. He's not getting to neutral. He doesn't have near enough hip flexion and swing. He doesn't get the full amount of knee flexion, but that's the least of his problems. He's really getting very little hip flexion and not much dorsiflexion and swing. But he has some really big stance limb instability there. And interestingly enough he's pretty far post. But he was kind of an interesting gentleman in that even in his chronic phase, he tended to be a little bit on the lower muscle tone side. But I will tell you, the other thing he told me is that he had been drilled on in previous therapy to not hyper-extend his knee. To not let his knee pop back as he said. And the way that he succeeded in that was just to always walk in a slight crouch, which is not a good solution either, right?

So let's go to the next, or actually let's go back to the slide. Sorry, let's go back to the slides. So we've talked through kind of his major deviations that we've seen there. Obviously he was walking very slowly, his gait speed was very slow, his endurance was very poor. He only got a few hundred feet in a six minute walk test. He had a significant fall risk. His balance measures were all really low. Are fairly low. And he had experienced one really significant fall just prior to starting therapy with me. I think this is probably not his actual measures at the time that video was taken, but I've created some impairment measures here for it.

They're probably pretty close. He had a little bit of limited range at his ankle. He only got to neutral there on the right. You can see his MMT scores there distally very, very low. I would say his plantar flexors, I gave him a one in my recollection here, but it could have been a zero. He actually had a little bit of dorsiflexor activation, but really poor endurance for it. If you had been able to hear him walk, you would hear that he had a foot slap with every step. So very, very weak dorsiflexors. His quads were as strong as muscle group, which is pretty common in patients with stroke. He did have some pretty good hamstring activation, but again, kind of a one repetition wonder for a three there. And as evidenced by us walking, some significant weakness in his hip

flexors, abductors, and extensors. So he had intact sensation which was great. He wasn't having any pain in the lower extremity which was important to ask about. He did have a bit of evidence of an extensor synergy at times when he was exercising and doing stuff, but really in walking that was not evident. But when you tested his spasticity with him laying supine, he did have a little bit of increased muscle tone in his plantar flexors or quadriceps. But when he walked, you just did not see evidence of that at all which is a good reminder that spasticity measure doesn't equate to function.

So we've talked about his gait deviations. What would be some specific interventions that you might have? And you can type in the chat box and I'll talk to you, but what would be some specific interventions that you might have to target his impairments? So of the impairments that we identified, what would you be thinking to do for this patient in terms of some interventions for this person? And it'd be great if you type in the chat box some answers. I know Amy you had a question. I will come back to that. I think it was about a study.

So I'll come back to that. But anybody else have any other... Improve plantar flexor strength. Yeah. Yeah, Fatima absolutely. Absolutely. Do you have any ideas about how to do that? Static standing and leaning forward. So something similar to what we talked about. Yeah. Yep. Definitely orthotics to control that tibial instability. Right now he's not doing that extensor thrust Elizabeth, but he's intentionally keeping a crouch to avoid that. Yeah, exactly. Clicking through here. Jennifer says, "Closed chain dorsiflexion to increase plantar flexion strength." Oh, yeah. So closed chain coming forward into dorsiflexion. Exactly. So we did a lot of wall falls with him, right? So those kinds of activities like my student was demonstrating lots of stuff in the wall. We did a lot of stuff. This was in his home. I was seeing him at home. We did a lot of stuff at his kitchen counter where I kept his feet back far enough that he had to then activate and come forward to improve his plantar flexor activation. We did a lot of stuff on a trampoline. I had like a little mini jogging trampoline. We did lots of activity standing on

that to try to make him a little bit unstable and sort of trick his plantar flexors and his dorsiflexors into working more. We definitely did stretching and mobilization, right? Don't forget your orthopedic skills. Don't forget your manual skill. So get in there and mobilize that joint as well. We did lots of things that elicited a balanced reaction. Lots of stuff where he was throwing, catching things that he had to do where he was forward to get those distal muscles to activate. And we actually did improve his strength with those type of activities. I know we're right at time, but I do want to show you the next two videos real quickly.

So this next one was the device he had when I started seeing him. This was what he had had since shortly after his stroke. It was a solid ankle AFO. I know you can't tell, but in this device he's doesn't really look that great. He looks better in that he's clearing his foot a little bit better. He's still kind of staying flexed. He actually now has this knee wobble. Looks almost like he's sort of fighting the device a little bit and that's because it wasn't really well fitting for him partly because he was a little bit tight. So this device wasn't really allowing him a smooth transition forward bringing his center of mass over his foot.

And I'll show you the next video the device that he went into which greatly improved his walking. I wish I had found a couple of videos, but this one that I'm about to show you was just sort of when he first got it video. His walking did improve, but we'll go to the next video and then we'll wrap up. So you can see this one he's still not perfect, but this one he's actually coming forward, getting his weight shifted forward. Sorry. You'll see as he passes back by here. He actually has a much more smooth transition through stance. He's still not quite getting fully extended like we would like, but a little bit better. And as we worked with him and we also made some adjustments in the device, it definitely smoothed out and improved and became more normal. So I'm not advocating any specific device, what I'm saying is look at your patient's walking closely and if the device that they're using isn't normalizing their walking, maybe

consider a different device or adjustments to the device that you have. So we can go back to the slides and I think there's at least a question here. Evidence doesn't show that the use of orthotics decreases muscle activity. Does it? Amy no, it doesn't. I'm glad you asked that. And obviously you ask it in a way that said it doesn't show that. Does it? So that must mean that you believe that it doesn't show that. The vast majority... Well, I shouldn't say the vast majority. Many, many therapists out there believe that use of an orthosis somehow decreases your muscle activity. And there's actually quite a few studies that show that to not be true. There's 11 or 12 of them to be exact. They're not all in stroke, but there's some studies that show muscle activity actually improves, there're many studies that show that it doesn't change. So, yeah. But that's a very common misconception and we saw that a lot in our research that we did. What is an orthosis? What is that orthotic? That orthotic is a ground reaction dynamic carbon fiber, carbon strut AFO. I don't know. There's not like a particular name for it, but it's a ground reaction design. And then what's restricting the motion in the device is a carbon fiber strut. And then Lauren you had a question. Oh, no. I didn't answer that one.

Yes, that's just the . Amy, you had a question. Was what's the study that showed not detrimental to sit to stand or stair climbing using joint or low profile AFOs?. I can't remember off the top of my head. I don't think they were all the same. I don't think they were all articulated. I think some of them were solid, but I can't tell you exactly. I'm sorry. Yeah. You need to go back and look at that. Would I please explain ground reaction? Sure Jamie. So a ground reaction if I. So a typical AFO, if I go back here to a picture real quick, so a typical AFO, the person comes in from the front, right? They stick their leg in from the front and the support part of the device is behind them. Has a posterior panel, right? That's the supporting piece. A ground reaction they're going to come in. In this one they're actually going come in from the top or they're going to come in from the back. This one they put their foot in from the top. But the panel where the support is in the front. So where they're encouraged to sort of put their weight into

is in the front. And so this is a device that was originally used in kids who had CP that crouch. The idea that when you give them that panel in the front, you can push them back up into that extension. And we started using this in some of our patients with stroke with the idea that if the support part of the device is in front, maybe that will encourage them to lean into the device. Sort of like you lean into a ski boot if you've ever snow skied. That they'll lean into the device, moving their tibia forward as opposed to seeking support behind them and pushing their tibia back. But that's a ground reaction device where the support panel is in the front. And every AFO actually provides some degree of ground reaction. The idea here is that you're harnessing the ground reaction force. The force that's generated as your foot hits the ground and starts to roll over, that you're harnessing that force to help to normalize the mechanics at the knee. Hopefully that answered that question. And I know I'm a little bit over. So any other questions? And I really apologize for whatever that weird a glitch in the sound was. That was spooky, but thanks for your patience while we got that sorted out. Oh, there's one more question. Oh, you're welcome. You're welcome.

- [Calista] All right, I think that's the last question that we had Jill. And thank you so much for presenting for us once again today.

- My pleasure.

- [Calista] And we're going to go ahead and wrap up today's course.

- Thank you.

- Have a great day, everyone. Thanks again, Jill.