

Lower Extremity Review

# ler:PEDIATRICS

May 2017



**Fine-tuning orthotic device  
prescription, fitting in CP**

**Growth-plate injuries:  
a diagnostic challenge**

## **PLUS:**

- Genotyping in Charcot-Marie-Tooth
- Gait tests for postconcussion effects
- Patellar maltracking and PFP etiology

# allard<sup>USA</sup>

Can you play with me?



Support for better life



kiddieGAIT™

Functional Heel-to-Toe Gait  
with stability and spring assist



kiddieROCKER®



S.W.A.S.H.®

Increased levels of function  
with sitting, standing and walking

allard<sup>USA</sup>

[www.allardusa.com](http://www.allardusa.com)

ALLARD USA, INC.  
300 Forge Way, Suite 3  
Rockaway, NJ 07866-2056

info@allardusa.com  
Toll Free 888-678-6548  
Fax 800-289-0809





iStockphoto.com #539281953

## news

### 5 Genetic mutations in CMT help predict phenotypic differences

*Ankle strength commonly affected*

By Greg Gargiulo

### 6 Gait metrics highlight gender differences after concussion

*Girls show more postinjury changes*

By Hank Black

### 7 Age-based patterns of patellar maltracking require tailored care

*PFP etiology differs in adults, kids*

By Katie Bell

## features

### 9 Fine-tuning orthotic device prescription, fitting in CP

The heterogeneity of cerebral palsy means individual responses to orthotic devices vary widely. Moving beyond standardized care to match orthotic prescriptions to each child's unique gait issues, as well as to their individual footwear needs, however, will likely improve outcomes for all.

By PK. Daniel

### 15 Growth-plate injuries: a diagnostic challenge

Physal trauma can be hard to spot, and mismanagement can disturb normal development and lead to lower extremity issues, such as limb-length discrepancy and abnormal biomechanics. A thorough clinical exam, including details of the moment of injury, is often key to accurate diagnosis.

By Shalmali Pal

## From the editor: Concussion's whole-body effects



As I was proofing pages for this month's *LER: Pediatrics*, my next-door neighbor called to say her 9-year-old daughter had fallen, hard on her head, while practicing gymnastics. She wanted to me to come and watch her baby while she took her older child to the emergency department. But, after a few minutes of us watching her daughter vomit and not respond to questions, my neighbor asked me to call an ambulance.

The paramedics took daughter and mom to the hospital, and I sat with my neighbor's baby, eventually returning to my editorial work, which included the story on page 6, "Gait metrics highlight gender differences after concussion." I now reviewed the work with more gravity, thinking about the seriousness of these injuries, and how effects linger, including those affecting the lower extremities.

Later that day, my young neighbor was admitted to a pediatric intensive care unit, where neurologists diagnosed concussion.

These head traumas, it turns out, raise risk for lower extremity injury for at least two years after concussion; the opposite is also true, with lower extremity injury upping risk for concussion. (See "Concussion repercussions: Studies explore lower extremity effects," *LER*, June 2016, page 13). And, as the news story in this issue reports, after concussion children walk more slowly and take shorter and fewer steps during gait.

Gait and concussion, it seems, are linked—dual-task gait metrics, for example, are good at revealing biomechanical postconcussion deficits, as well as gender differences suggesting girls have more postinjury problems. Luckily, the youth sports community is heeding research about the short- and long-term effects of concussion. US Soccer, for example, in 2016 banned heading the ball for kids younger than 11, and restricted it for those aged 11 to 13.

Lower extremity practitioners have an important role to play in concussion rehabilitation, helping patients improve gait and regain strength losses common with the injuries, and with return-to-sports decisions.

My neighbor's daughter is home now, and with time, I hope she'll recover completely, perhaps with help from a lower extremity specialist.

Emily Delzell, Senior Editor

# **MAXIMIZE RESULTS** with **MINIMAL RESTRICTION**

for Treatment of all Lower Limb  
**Bowing Deformities.**

*Outstanding  
Patient  
Compliance*

Independent or Dependent  
Tibio-Femoral  
Adjustment Capabilities



Auto Aligning  
**V-VAS™**  
Polycentric Joints



Case Studies referring to our  
Pediatric Custom KAFO's  
and our Auto Aligning  
V-VAS™ Joints are  
available on our website  
and/or upon request  
via email or fax.



**800.837.3888**  
**AnatomicalConceptsInc.com**



# Genetic mutations in CMT help predict phenotypic differences

## Ankle strength commonly affected

By Greg Gargiulo

Researchers are inching closer to being able to predict specific symptoms of Charcot-Marie-Tooth disease (CMT) based on a child's genotype, but the variability found in a recent Australian study suggests that, for now, patients should still be assessed and managed individually.

The cross-sectional study identified notable phenotypic differences within and among several common CMT genotypes, including functional limitations and self-reported impairments.

"We were able to demonstrate that significant impairment occurs from the earliest stages of the disease, with ankle dorsiflexion strength and functional hand dexterity being the most affected of all measurements," said Kayla Cornett, a PhD student who conducts research with the Sydney Children's Hospital Network at the University of Sydney in Australia. "Furthermore, the mutation-specific manifestations provide additional information on the difficulties experienced by the different genetic subtypes."

CMT is characterized by distal weakness, foot deformity, sensory loss, and gait difficulties, but it is not completely clear how frequently and to what extent these manifestations and functional limitations occur in different CMT genotypes.

The study evaluated 520 children and adolescents (246 girls) aged 3 to 20 years using the 44-point CMT Pediatric Scale (CMTPedS). The CMTPedS measured hand dexterity, strength of hand grip, ankle dorsiflexion and plantar flexion, lower limb sensation, gait, balance, and function. The resulting raw scores were compared with age- and sex-matched normative reference values.

The most prevalent CMT genotypes in the sample group were CMT1A (48.5%), CMT2A (6%), CMT1B (2.9%), CMT4C (2.5%), and CMTX1 (1.9%). Disease severity according to the CMTPedS represented almost the entire spectrum of the scale, and scores differed significantly among each of the five most common genotypes.

The most affected items on the CMTPedS for all genotypes were ankle dorsiflexion strength (82.3%) and hand dexterity (56.5%), but certain physical impairments

were more prevalent in some genotypes than others.

"Although ankle dorsiflexion strength was the most affected, it is not the only affected aspect, and different children will have different goals and outcomes they want to achieve," Cornett said. "Therefore, specific clinical recommendations should still be made on a patient-by-patient basis."

The findings were published in June 2016 by *JAMA Neurology*. A longitudinal study on the same study group is ongoing.

More frequent follow-up with patients with CMT genotypes linked to greater symptom severity may be warranted.

Participants with CMT2A and CMT4C had significantly weaker ankle plantar flexion and dorsiflexion strength, as well as lower long jump and 6-minute walk test scores, than those with CMT1A and CMTX1. Genotypes CMT1A and CMTX1 had significantly better balance and were less severely affected than the other three genotypes, while participants with CMT2A were significantly weaker for all strength measurements and were most severely impaired, with a CMTPedS mean score of 30.

CMTPedS scores for children with CMT4C and CMTX1 were also found to progress quicker in childhood than adolescence, while the progression was faster in adolescence for CMT1B and CMT2A.

"According to this, if a five-year-old child with CMT4C does not yet have balance issues, we might expect them to develop them within the next five years. However, there is individual variability," Cornett said. "Patients with CMT1B also had significantly impaired balance compared to other types, so we would expect similar difficulties to arise in them."

The findings suggest clinicians may want to have more frequent follow-ups when dealing with genotypes associated with



Image courtesy of the Charcot-Marie-Tooth Association.

greater symptom severity, Cornett said. Ultimately, however, treatment should still be decided on an individual level, she said.

This is equally true for the study findings that have implications for orthotic management, said David Misener, CPO, of Clinical Prosthetics and Orthotics in Albany, NY, who has CMT himself and whose son was a CMT1B participant in the study.

"I don't think I'll change my treatment recommendations at all for CMT patients based on this study, as I just don't think there's enough delineation between all the different types here," Misener said. "So, I'll still base treatment on phenotype over genotype: basically how do they present and how do they look, and then it's always important to see patients on a pretty routine basis after I give them a device."

More long-term data on the topic are still needed, he said.

"It's an awesome starting point, but we just need more people in these studies to make them more statistically significant," he said. "I'd love to see more in-depth research on phenotypic variability, and I'd love to get a better understanding of time and rate of change and know what the rate of change really is. I don't think we have enough here to garner that information."

In the meantime, the longitudinal, natural history study may help Cornett and her team to better answer some of the many remaining questions.

"When we follow individual children over time and look at progression, we will be better suited to answer the questions on progression and where to target treatment," she said. <sup>(ler)</sup>

*Greg Gargiulo is a freelance medical writer based in San Francisco.*

#### Source:

Cornett KM, Menezes MP, Bray P, et al. Phenotypic variability of childhood Charcot-Marie-Tooth Disease. *JAMA Neurol* 2016;73(6):645-651.

# Gait metrics highlight gender differences after concussion

## Girls show more postinjury changes

By Hank Black

A recent study's findings related to dual-task gait analysis in adolescents add to the body of evidence suggesting that concussion effects differ between male and female patients.

The findings, epublished April 1 by *Gait & Posture*, also suggest dual-task costs—the percentage change from a focused-attention single-task condition to a divided-attention dual-task condition—are useful for comparing characteristics such as gender among a group of individuals postconcussion, but traditional gait metrics may distinguish better between concussion and control groups.

Previous studies, including a recent meta-analysis, have found female patients have greater visual memory impairments and report more severe symptoms after concussion than male patients. But it previously was unknown whether dual-task gait differences existed between genders postconcussion.

The current study noted, “Our results indicate that during tasks with dynamic equilibrium and control challenges such as gait, paired with a cognitive task, differences exist between genders.”

Lead author David R. Howell, PhD, ATC, a clinical researcher at The Micheli Center and Boston Children's Hospital, said those differences, which are independent of gender differences in body size, may be useful in determining individualized evaluation and management of functional recovery following sports concussion. He noted most prior studies of postconcussion gender differences have used subjective symptom inventories.

“We were interested in whether the objective evaluation of postconcussion deficits, such as instrumented dual-task gait assessment, would provide additional insights,” he said.

The researchers recruited 35 participants (49% girls; mean age  $15 \pm 2.1$  years) who were postinjury ( $7.5 \pm 3$  days) and compared them with 51 uninjured controls (51% girls; mean age  $14.4 \pm 2.1$  years). Both groups completed a symptom inventory and

single- and dual-task gait assessments.

They also evaluated average speed, cadence, stride length, and double support time. To suss out the individual differences, the researchers chose the dual-task cost as the primary outcome variable.

Investigators found no significant differences between genders in postconcussion measures of symptom severity. Dual-task gait metrics, however, showed girls with concussion walked with lower cadences than female controls and boys with concussion. Stride length differed between concussion and control groups and between genders in both groups; all concussion participants walked with shorter stride lengths than controls.

Identifying specific deficits among patient subgroups could enhance clinicians' postconcussion counsel.

A wide variation in dual-task costs was found in the concussion cohort, but a significant difference was found only in gait cadence: Girls with concussion walked with significantly greater dual-task costs than boys with concussion (there was no significant difference between genders in the control group).

The researchers hope identifying specific deficits among patient subgroups will allow clinicians to provide better counsel after injury and direct patients to appropriate clinical pathways, Howell said, noting they expect their findings to be used as part of an in-clinic evaluation rather than field-side assessment.

“Since we conducted all testing in a hallway nearby the exam room, our hope is that clinicians may be able to adapt dual-task paradigms into their everyday practice to understand if an athlete has recovered the ability to walk and think simul-




taneously,” he said. “We are hoping to use this study as a basis to also gather data that answer some of the physiologic underpinnings of our findings. By addressing this, we hope to help improve how clinicians tailor management plans to different individuals based on their innate characteristics, as well as their postinjury function.”

Daniel Herman, MD, PhD, of the University of Florida, Gainesville, said the varied effects of concussion on neuromuscular control are relevant to both the clinical use of dual-attention tasks, as well as to postrecovery complications, such as risk for musculoskeletal injury.

“In general, the paradigm of dual tasking can help us identify differences between groups [whether gender or based on concussion status],” said Herman, assistant professor in the division of Physical Medicine and Rehabilitation, Sports Medicine, and Research in the Department of Orthopedics and Rehabilitation.

He believes the sports medicine community should be using dual-task analysis more extensively in concussion evaluation, injury risk assessment, and injury rehabilitation.

“This is another strong manuscript by David Howell, who really has become a leader in sports concussion, but particularly in the area of the effects of concussion on gait,” he said. 

Hank Black is a freelance writer in Birmingham, AL.

#### Sources:

Howell DR, Stracciolini A, Geminiani E, Meehan WP 3rd. Dual-task gait differences in female and male adolescents following sports concussion. *Gait Posture* 2017;54:284-289.

Howell DR, Osternig LR, Chou L-S. Dual-task effect on gait balance control in adolescents with concussion. *Arch Phys Med Rehabil* 2013;94(8):1513-1520.

Brown DA, Elsass JA, Miller AJ, et al. Differences in symptom reporting between males and females at baseline and after a sports-related concussion: a systematic review and meta-analysis. *Sports Med* 2015;45(7):1027-1040.

# Age-based patterns of patellar maltracking require tailored care

## PFP etiology differs in adults, kids

By Katie Bell

Patellar maltracking persists in adolescent girls with patellofemoral pain (PFP) even as symptoms improve, according to a study from Maryland, which suggests the etiology of PFP differs between adolescents and adults and should be managed accordingly.

The longitudinal study found no changes in patellar maltracking patterns in 10 knees from six girls with clinically diagnosed PFP as they matured from mid- to late adolescence.

The unchanged patellofemoral maltracking suggests anatomic and kinematic abnormalities contributing to PFP during mid-adolescence continue during skeletal maturation, rather than evolving to resemble those seen in adults, according to the authors. The findings suggest age of onset is important to PFP's etiology and that interventions tailored to age-based maltracking patterns may improve outcomes.

Corresponding author Barry P. Boden, MD, who specializes in sports medicine at The Orthopaedic Center, a division of Centers for Advanced Orthopaedics, in Rockville, MD, noted that with PFP, "adolescent-onset is associated with lateral shift or lateral tracking in the trochlea, while adult-onset PFP is associated with patella tilt."

Boden and colleagues used dynamic magnetic resonance imaging (MRI) to acquire 3D patellofemoral kinematic data during active extension and flexion when participants were aged a mean of 14 years, with follow-up when participants were aged a mean of 18.5 years.

The investigators obtained 3D patellofemoral kinematic parameters with the participants situated supine in an MRI scanner. Participants rhythmically flexed and extended their knees at 30 cycles per minute, with guidance from an auditory metronome. Velocity data in the three cardinal planes were used to identify the position of the patella and tibia relative to the femur during the cycle.

At initial and follow-up visits, investigators evaluated participants' knees, including Q-angle, assessment for a J-sign, and lateral patellar hypermobility, and recorded age,

height, weight, and body mass index. They compared pain score based on a visual analog scale (VAS) and anterior knee pain (AKP) scores across initial and follow-up visits. Participants reported hours spent doing impact and nonimpact physical activities.

All participants reported improved PFP symptoms at follow-up; AKP scores improved 35% and VAS pain scores during provocative activities improved 72%. One participant reported complete resolution of PFP symptoms.

Investigators found no differences in patellar maltracking from initial to the follow-up visits. Meanwhile, a decrease in hours engaged in impact physical activities was reported by all participants at follow-up, with two reporting they discontinued all physical activity.

Although symptoms improved, all patients reported at follow-up reduced time spent in impact activities.

On initial evaluation, 50% of patients had extreme lateral patellar displacement at 10° of extension; the rest had nonextreme patterns. At follow-up, all participants demonstrated the same kinematic profile as at baseline. The average distance between the tibial tuberosity and trochlear groove at initial and follow-up visits was 11.6 and 13 mm, respectively, for the whole study group, and 14.8 and 14.2 mm, respectively, for the extreme maltrackers. No participant reported a history of dislocation during either visit.

The study, published in February in *The Orthopaedic Journal of Sports Medicine*, didn't evaluate dislocators, who often have patella alta and trochlear dysplasia, Boden said.

Symptom improvement didn't result from a change in patellofemoral tracking, he said, but rather from other causes, such as

Patients provided 3D patellofemoral kinematic data by lying in an MRI while rhythmically flexing/extending their knees.




Image reprinted with permission from Carlson VR, Boden BP, Sheehan FT. Patellofemoral kinematics and tibial tuberosity-trochlear groove distances in female adolescents with patellofemoral pain. *Am J Sports Med* 2017;45(5):1102-1109.

reduced participation in impact physical activities.

Physical therapy, including activity modification, is currently the best treatment for PFP in children and adults, said Boden.

"Knee braces can be helpful for stabilizing the patella and providing proprioception, and surgery is helpful in cases that don't respond to a minimum of six to nine months of nonoperative treatment," he added. "For the adult, the lateral release may be more appropriate, whereas [centering] the patella may be more appropriate for adolescents."

Michael Skovdal Rathleff, PhD, associate professor, and Sinead Holden, PhD, visiting researcher, in the OptiYouth research group at the Research Unit for General Practice at Aalborg University in Denmark, said young adolescents with PFP don't display the same strength deficits as older adolescents or adults with the condition. Although the study didn't look at strength deficits, Rathleff and Holden said this strength difference calls into question the rationale for focusing on strength training and exercise therapy in these young adolescents.

"To keep youth active, practitioners can focus on helping adolescents control their sports participation and manage load. Initially this can include education about activity modification, enabling them to be physically active in activities that do not aggravate their knee pain, or cause a flare in symptoms," Rathleff and Holden noted in an email interview. "To support them in returning safely to sport, the focus should be a graded reintegration to previous activity levels, helping them find the 'sweet-spot,' rather than an 'all or nothing' approach to starting and stopping exercise and activity." 

Katie Bell is a freelance writer based in New York City.

Source:

Carlson VR, Boden BP, Shen A, et al. Patellar maltracking persists in adolescent females with patellofemoral pain. *Orthop J Sports Med* 2017;5(2):2325967116686774.



“Amazing speakers. I learned  
so much, thank you.”

– Mari P. CPO

CASCADE  
dafo  
INSTITUTE

# Practical education for exceptional care



**NEW Beyond the Basics online course:**

## Using DAFOs in Treatment Plans for Patients with Cerebral Palsy

*Two respected experts—a neurologist and an orthotist who’ve worked together for many years at a world-renowned CP center—share their knowledge and strategies for bracing patients with CP.*

(2.5 credits)

We offer free ABC-approved online courses. Visit our website and check out the **Cascade Dafo Institute**, our education hub, to find out more.

**Take all our free online courses  
and earn up to 10.25 credits!**



Keith Smith, MD, LO, MACP



Dr. Janice E. Brunstrom-Hernandez

**cascadedafocom**



Helping kids lead healthier, happier lives®

1360 Sunset Avenue, Ferndale, WA 98248 | ph: 800.848.7332 | fax: 877.856.2160 | intl: +00 1 360 543 9306

CASCADE  
dafo





Brittany, a patient at Shriners Hospital for Children—Chicago rides an adaptive bike with a recreation therapist. (Image courtesy of Shriners Hospital for Children—Chicago.)

## Fine-tuning orthotic device prescription, fitting in CP

The heterogeneity of cerebral palsy means individual responses to orthotic devices vary widely. Moving beyond standardized care to match orthotic prescriptions to each child's unique gait issues, as well as to their individual footwear needs, however, will likely improve outcomes for all.

By P.K. Daniel

J.M. is a chatty little 8-year-old girl with long brown hair. She has hemiplegic cerebral palsy (CP) and has been treated at Shriners Hospital for Children—Chicago since 2013. She has a foot drop, knee hyperextension, and decreased hip motion. Her condition used to require botulinum-A toxin (Botox) injections every three to six months. Her ankle foot orthosis (AFO) gave her sores.

But last year, she received a tuned AFO—carefully adjusted for optimum alignment in combination with footwear—while under the care of senior physical therapist Nancy Scullion, PT, MPT, PCS, who has been treating children with CP at the Rehabilitation and Motion Analysis Laboratory of Shriners Hospitals for Children—Chicago for two decades. J.M. wears her tuned brace daily. Her knee and hip range of motion, plus her ground reaction forces, have normalized. She has gained a normalized gait pattern, no longer has sores, and doesn't need Botox.

Because of the heterogeneous nature of CP, it became apparent to Scullion that standard AFOs aren't always the answer.

"One of the difficulties with prescribing orthotic devices for children with cerebral palsy is the cookie-cutter response that has taken place over the course of modern medicine," Scullion said. "Many physicians have a particular style of AFO that they like to use. They don't necessarily customize it to work for that particular patient's spasticity, range of motion, strength, or walking pattern. So sometimes, a child will have a brace that is less than optimal for their gait deviation."

Scullion has had success with treating hemiplegic CP patients like J.M.; she uses instrumented gait analysis to document the effects of tuning-based treatment in these children, using the tuned orthotic device on one side and nothing on the other side.

"They're almost like their own control," she said. She has been able to show normalized range of motion at the knee and the hip, as well normalized joint forces and muscle lengths, while wearing the tuned brace. "If you compare their right and their left side, except for the foot and ankle, which are rigidized inside the brace, they're essentially normalized," she said.

Half of those diagnosed with cerebral palsy have been prescribed standard AFOs to aid in walking, according to United Cerebral Palsy and the CDC.



## Diverse condition, device responses

The umbrella term of cerebral palsy, the most common motor disability in childhood with more than three-quarters of a million people in the US exhibiting one or more of its symptoms, can include a completely dependent, wheelchair-bound child, as well as an independent one who walks without an assistive device and requires minimal intervention. And yet, according to United Cerebral Palsy and the Centers for Disease Control and Prevention, half of those diagnosed with CP have been prescribed standard ankle foot orthoses to aid in walking.<sup>1</sup>

The overarching condition of CP includes spastic, which is characterized by muscle stiffness and permanent contractures; athetoid, which has uncontrolled, slow, writhing movements; and ataxic, marked by poor coordination and balance.<sup>1</sup> Additionally, within each type, there are differences involving motor function (GMFCS [gross motor function classification system] level; levels range from I-V, with disability increasing at each level), spasticity, and specific neuromuscular issues. For example, crouch gait (limited knee extension), ankle equinus (limited dorsiflexion), or hallux valgus can be at play. Then there are basic demographic differences, like age, height, weight, and gender.

These variations can make it difficult to study the effectiveness of AFOs and other orthotic devices in children with CP. Typically, study results on orthotic interventions are presented as averages for the study population. The problem with that approach in a heterogeneous group is that even if there is no significant average effect of the intervention, there still may be some patients who respond positively. Conversely, even if a study finds a benefit for the

Industry Leaders Specializing in Pediatric Orthotic Designs

## Static-Progressive Hinge for Pediatric Patients

This small, low profile, and lightweight joint is the perfect solution for pediatric patients. Manufactured from high grade stainless steel, this static-progressive joint was designed for lasting durability and strength on any pediatric, non-ambulatory upper and lower extremity brace. It is easily adjusted to meet specific patient needs.

**Call today for more information!**

**the spiro joint**

**surestep**

grow with us

surestep.net | 877.462.0711



group overall, there may still be some kids who don't respond well.

"Most of the research studies investigating the efficacy of AFOs show wide variability in AFO performance," said Andy Ries, MS, an engineer at the Gillette Children's Specialty Healthcare, Center for Gait and Motion Analysis at the University of Minnesota in St. Paul. "What works for one individual doesn't necessarily work for another. We see similar trends for all types of interventions in CP."

For example, Bradford C. Bennett, PhD, a lecturer in the Department of Kinesiology at San Francisco State University in California, analyzed the effects AFOs have on the energy recovery and mechanical work done by children with CP while they walk. The study included a convenience sample of 21 children who wore bilateral AFOs custom-made by the Prosthetics and Orthotics Department at the University of Virginia (UVA) in Charlottesville. All tests were conducted in UVA's Motion Analysis and Motor Performance Laboratory.

"In my paper, we found that statistically for the group, AFOs had little effect on the amount of work performed while walking," Bennett said.<sup>2</sup>

However, a more detailed look showed that for eight participants, the use of AFOs resulted in reduced work to walk (up to 45% less); for six participants there was no difference in the amount of work done (within 10% of each other) with or without AFOs; and for seven of the participants, walking with their AFOs required more work (up to 35%) to walk.

"It is quite clear that cookie-cutter solutions do not work for these patients, and treatments need to be adapted to the individual," said Bennett.

A growing number of other studies have reported similar variability in AFO response.<sup>3-5</sup> And researchers from the Netherlands reported in 2016 that tuning AFOs was associated with improved knee flexion during stance across a group of 15 children with spastic CP and crouch gait.<sup>6</sup>

## Limitations of standardized care

There has been an observed standardized treatment of CP patients, such as typically prescribing a hinged AFO. But Cary H. Mielke, MD, chief of staff at Shriners Hospital for Children—Twin Cities in Minnesota, pointed out how doing so can have negative effects in children with crouch gait.

"They are kind of taking the thinking out of medicine," Mielke said. "If you have this, then this is what you do. A lot of protocol-driven thinking is going on in medicine now."

Practitioners at Shriners have adopted the mindset that children with CP may benefit from a more individualized orthotic management of their condition rather than a one-device-fits-all approach.

"It's true for all our facilities," said Shriners—Central Region Senior Director of Public Relations Tammy Robbins. "We are known for taking an individualized approach to all our patients. Especially with cerebral palsy, because it presents itself so uniquely in each child."

Mielke said a wide variety of AFOs can be used for CP. For a high-tone child, like one who has experienced a near drowning, Mielke said he would likely use a solid AFO to block tone. But, for a fairly functional hemiplegic child with a slight drop foot, he would order a flexible leaf spring AFO. And for a hypotonic, ligament-lax, developmentally delayed child, he would go with a supramalleolar orthosis (SMO).

"We tend to tailor it to the patient's needs," Mielke said. "You

*Continued on page 12*

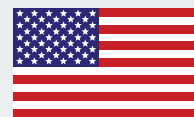
# Pediatric Noodle AFO

## Advanced Carbon Fiber Brace



Anterior Cuff

Posterior Cuff



**Handcrafted  
in the USA**

## 30 Day Unconditional Guarantee!

If for any reason during the initial 30 day trial period the practitioner or wearer is not completely satisfied with the Pediatric Noodle AFO it may be returned for a refund.

## FUNCTION - STYLE - VALUE



**CARBON FIBER SPECIALISTS**

**800-919-3668**

**WWW.KINETICRESEARCH.COM**



An orthotist at Shriners Hospital for Children—Twin Cities works on a custom device. (Image courtesy of Shriners Hospital for Children—Twin Cities.)

Owen introduced the concept of tuning—ie, aligning an AFO in combination with a patient's footwear, positioning the ankle in the orthotic device, and modifying the footwear to optimize the patient's gait pattern. The tuned orthotic device meant the ankle wouldn't have to be forced into 90°, an angle that can cause the calf to spasm when the knee is straightened. With the tuned orthoses, the foot is angled downward, mimicking the child's natural dorsiflexed position. Practitioners can add heel lifts to the brace or the shoe.

Scullion started experimenting with this concept around 2014. She initially faced resistance, even at Shriners, because, as she said, "The recipe said to give the patient an orthosis set at zero

degrees." But Scullion has successfully brought most of the doctors she works with on board.

don't order the AFO necessarily for the diagnosis, but for what you're seeing clinically."

Mielke emphasized that he isn't making a treatment plan unilaterally. Shriners practitioners take a multidisciplinary approach. The team coordinating care with the patient's family may include the orthopedist, an orthotist, and a physical therapist.

"We find a team effort, along with guidance from the family, is the best way to go," he said.

Variability in treatments, however, is not always available to CP patients. Scullion explained that any physician, including a primary care physician or a pediatrician, can prescribe an AFO. It doesn't have to be a physician who specializes in CP, pediatric orthopedics, or pediatric neurological disorders, or who is familiar with gait analysis or the gait deviations associated with CP. Sometimes the result is a lack of individualized treatment. Scullion said she has observed this in rural areas, where access to an orthotist, physical therapist, or other lower extremity specialist may be limited.

"At Shriners, we're looking at the patient individually and having a discussion about what type of bracing would serve the patient best," Scullion said.

Shriners—Chicago started dabbling in tuned bracing in 2014 after Scullion was introduced to the practice by world-renowned Welsh physiotherapist Elaine Owen, MBE, MSc, SRP, MCSP.<sup>7</sup>

The long-held paradigm for orthotic prescriptions called for the ankle of the AFO to be at 0° of dorsiflexion. The ankle joint was vertical to the plantar surface of the foot, while the foot was at a 90° angle to the calf. The ankle portion of the device would either be solid—like a ski boot—or articulated/hinged to allow motion at the ankle, but still forcing the foot into a 90° angle regardless of the patient's dorsiflexion availability.

Owen had questioned why the practice was to fight against children's spasticity when it would ruin kids' feet, Scullion said, noting, "We would see kids' feet basically shoved into a position that they couldn't naturally achieve."

degrees." But Scullion has successfully brought most of the doctors she works with on board.

## More positives for tuning

Another beneficiary of the tuned-AFO approach is A.B. He is a 13-year-old, bespectacled, fair-haired boy who loves sports. He has bilateral diplegic CP, and his old AFOs caused his skin to break down. His calf and ankle musculature were weak, causing his feet to deform within the brace.

"You could get the foot inside the brace, but once he stood up and straightened his knees, the foot was able to find its own path inside the brace," Scullion said. "He couldn't walk long distances. He couldn't wear his braces all day every day because he would get blisters or other skin irritations."

Now, A.B. wears his braces all day. He can ride his bike to and from school. He goes up and down the stairs at school by himself. He is independent at school. His alignment is improved when he is standing and walking.

"Out of the brace, these patients still have the affected limb, but in the brace, they're normalized," Scullion said. "If I can get a patient young enough to accept the tuned orthotic [device] then we can stave off any surgical intervention or Botox intervention and train the muscles in the knee and the hip to walk in a more normalized pattern."

Scullion said another way Shriners has been successful in enticing CP patients to continue wearing AFOs as teenagers, in addition to the individualized approach, has been moving them to a carbon-fiber or lighter-weight hybrid material.

Ries, the lead author of a study on the efficacy of AFOs on improving gait in children with CP that appeared in the September 2015 issue of *PM&R*, agreed that one likely explanation for the variability in AFO performance is the heterogeneity in the CP population, but also offered a further consideration.<sup>8</sup>

"Another likely explanation is the wide variability in AFO design




and quality itself,” Ries said. “For example, two custom-fabricated AFOs that are both formed on the same mold can have different functional properties [eg, ankle stiffness] due to differences in how thick the copolymer shell is made during fabrication or how much material is trimmed away during the fitting process. The true reason for the variability in AFO performance is likely to be a combination of both these influences.”

The Center for Gait and Motion Analysis in St. Paul has been investigating AFO performance in three areas, Ries said.

“First, we have focused on utilizing advanced statistical techniques to predict the performance of various AFO designs for an individual,” he said. “This would allow us to recommend the AFO design that is predicted to provide the best response on a case-by-case basis.”

He noted that while his group’s retrospective results seem promising, they still need to be validated in a prospective manner.

“We are collaborating with other researchers to develop a robotic AFO that will be capable of emulating key passive AFO qualities,” Ries said. “We envision using this new tool to identify the optimal AFO design for an individual by systematically altering the qualities of the robotic AFO during an evaluation session. From this, a custom AFO can then be fabricated with the optimal qualities found for that individual.”<sup>8</sup> 

References are available at [lerpediatrics.com](http://lerpediatrics.com).



A patient with CP at Shriners Hospital for Children—Chicago wearing his customized AFOs. (Image courtesy of Shriners Hospital for Children—Chicago.)

 <p>seamless AFO socks</p>	 <p>KPX16 / KPX16VEL</p>		 <p>KPM11 &amp; KP096</p>
 <p>HEEL ENTRY DESIGN</p> <p>KPHEELT</p> <p>cut-line 3.5MM under upper edge</p> <p>KPHEELN</p>	<p>Innovatively designed triple width double depth shoes for AFO's</p>		 <p>KPR11 / KPR11VEL</p>
 <p>KPN16 / KPN16VEL</p>	 <p>KPS16 / KPS16VEL</p>	 <p>KPW11 / KPW11VEL</p>	
 <p>KPLCW / KPHTP</p>	 <p>KPB11</p>	 <p>KPSAND &amp; KPSAND11</p>	
<p><a href="mailto:footwear@keepingpace.com">footwear@keepingpace.com</a>   (888) 526-0020   <a href="http://www.keepingpace.com">www.keepingpace.com</a></p>			



NEXT STEPS<sup>2</sup> NEW FEET

## Our products include:

Preemie AFO Pair and Bar

Ponseti® AFO Pair, sizes 0000-12

Ponseti® AFO Pair, sizes 0000-6

Ponseti® AFO Pair with Toe Stilt, sizes 2-11

Ponseti® AFO/PFS Pair, sizes 00-12

Ponseti® AFO/PFS Pair with Toe Stilt, sz 2-11

Ponseti® Extra Short Bar

Ponseti® Short Bar

Ponseti® Long Bar

Night ADM (Abduction Dorsiflexion Mechanism)

Bar Hardware Kit

Pressure Saddle, small

Pressure Saddle, large

AFO Socks, 3 pack

Dorsi Ramp

The Parent's Guide to Clubfoot

My Clever Night-Night Shoes

Ponseti® Clubfoot Model

Cast Application Rubber Legs and Stands

Five Stage Cast Model

Tenotomy Model



Clubfoot treatment just got easier! Order online and enjoy FREE SHIPPING (including 2nd day air and international) on all orders!

[www.mdorthopaedics.com](http://www.mdorthopaedics.com)  
877-766-7384





iStockphoto.com 462582573

## Growth-plate injuries: a diagnostic challenge

Physal trauma can be hard to spot, and mismanagement can disturb normal development and lead to lower extremity issues, such as limb-length discrepancy and abnormal biomechanics. A thorough clinical exam, including details of the moment of injury, is often key to accurate diagnosis.

By Shalmali Pal

In pediatric patients, two things have a high degree of certainty: They will grow, and they will injure themselves. These two inevitabilities often overlap in the form of physal, or growth-plate, injuries. Involvement in sports, or other organized physical activities, may be a primary reason for physal injuries—it's estimated that 25% of all childhood injuries occur during sports, and young athletes (aged 5-18 years) account for 40% all sports-related injuries that turn up at the emergency department (ED).<sup>1</sup>

And that's where physal injuries can get complicated, as recognizing and managing them may not be as forthright as in adult patients, explained Nailah Coleman, MD, a pediatric sports medicine specialist at the Children's National Health System in Washington, DC, and a spokesperson for the American College of Sports Medicine.

"If the child presents to an adult-intensive ED, those physicians may not be as knowledgeable about physal injuries, especially if they don't see [the injury] that day on an x-ray," she said. "They may suspect that it's a fracture, but not treat it as one initially. The child may return home thinking that it's just a sprain, but then they have continued pain, possibly for months."

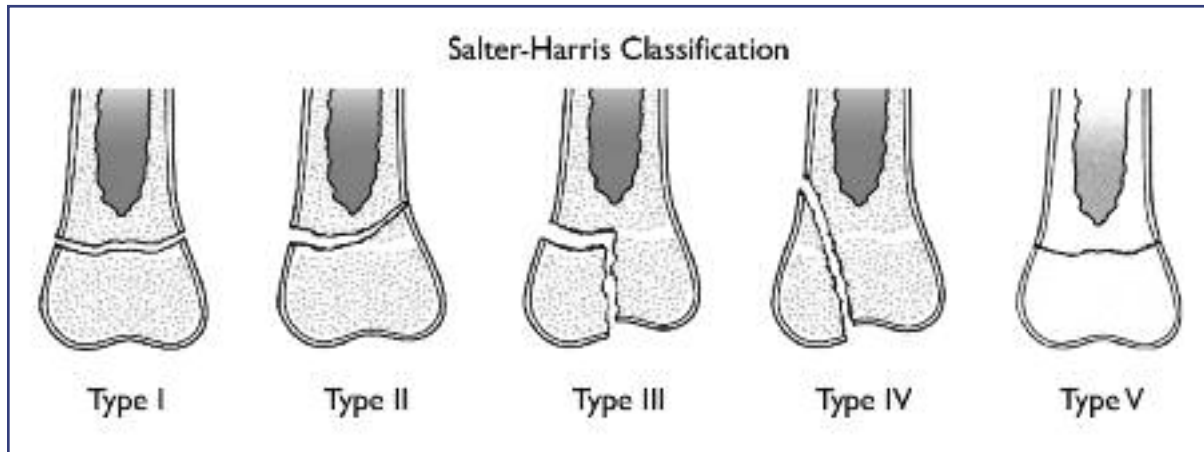
"Sometimes, it's an issue with the family," added Coleman, who also serves on the leadership board of the National Youth Sports Health & Safety Institute. "They come to the ED right after the injury occurs, but they want to believe that it's just a sprain because they don't want to deal with a broken bone and the longer recovery time that will take."

Whatever the reason, missing or misdiagnosing physal injuries can have long-term effects for a child's growth and development. Mismanaged physal injuries can lead to long-term complications, including growth disturbance and abnormalities such as limb-length discrepancy, angular deformity, and altered joint mechanics.

### Physal vs apophysal

First, some basic definitions: The physis is located at the distal portion of long bones. It's composed of cartilage that allows the

The growth plate is the weakest link in immature skeletons and when injured, can exhibit complete growth arrest, be impaired partially, or develop normally.



The Salter-Harris system classifies five types of fractures localized to the growth plate of a bone. (Image courtesy of the American Academy of Orthopaedic Surgeons.)

bones to expand, lengthen, and ultimately ossify when skeletal maturity is reached.

“Physeal centers close from distal to proximal, with the last being the clavicle, which may remain open into a person’s early twenties. Prior to closure, while in the cartilaginous state, the physis is prone to failure with abnormal traumatic or chronic stress. The growth plate is the weakest link in the immature skeleton and when injured, can exhibit complete growth arrest, be impaired partially, or develop normally. The potential for growth disturbance makes identifying and appropriately managing a physeal injury a high priority,” wrote Donna Merkel, PT, and Joseph T. Molony Jr, PT, in a review article.<sup>1</sup>

Although the term “growth-plate injury” is used in a global sense, there are two types of these injuries. True physeal injuries are fractures localized to the growth plate of a bone. These injuries are further classified by the Salter-Harris classification system. There are five types of Salter-Harris fractures:<sup>2</sup>

- Type I: through the physis, or growth plate
- Type II: involve the physis and metaphysis
- Type III: involve the physis and epiphysis
- Type IV: involve the physis, metaphysis, and the epiphysis
- Type V: compression injury of the physis

Then there are apophyseal injuries that occur at a secondary ossification center and the site where tendons attach to bone. In children, muscles and tendons tend to grow slower than bone, creating tension at the apophysis. As a result, force or trauma can lead to an avulsion of the apophysis from the attachment site to the bone.

The most common areas for apophyseal injuries are the hip and pelvis, as the hamstring muscles of the posterior thigh attach to the ischial tuberosities, and the rectus femoris muscle attaches to the anterior inferior iliac spine.

Other areas of apophyseal avulsion fractures are the anterior superior iliac spine, greater and lesser trochanter of the femur, the tibial tubercle, and the base of the fifth metatarsal in the foot.<sup>2</sup> For instance, tuberosity avulsion fractures can cause pain, tenderness, local bruising, and swelling at the base of the fifth metatarsal. Although nondisplaced tuberosity fractures are usually treated conservatively—a posterior splint followed by a molded, nonweight-bearing, short leg cast—orthopedic referral will be necessary for fractures that are comminuted or displaced; fractures that involve more than 30% of the cubo-metatarsal articulation surface; and fractures with delayed union.<sup>3,4</sup> Although most fractures of the prox-

imal portion of the fifth metatarsal do respond well to appropriate management, long-term complications of these untreated fractures include delayed union, muscle atrophy, and chronic pain.<sup>3,4</sup>

True physeal injuries are more likely to result from trauma, but they can happen either through contact or noncontact in a sport, explained Molony, a pediatric rehabilitation specialist at the Hospital for Special Surgery (HSS) in New York, NY.

An example of a traumatic injury would be “when a player goes to cut, twists their ankle, and sustains a Salter Harris type I of the distal fibula,” said Molony, the coordinator for the HSS Young Athlete Program. Alternatively, a player could take a hit to the knee and the fracture can occur. Pain and discomfort from a physeal injury will most likely be felt immediately.

On the other hand, an apophyseal “nontraumatic [injury] would be from continuous, low-load accumulation over time that is generally going to lead to a Salter I, as well, but it’s going to gap the physis/apophysis a bit, or create irritation across it,” Molony explained, adding that a Salter II and above in the overuse category is not likely.

That irritation may take some time to build up and cause problems for the player. Molony gave the example of a midfielder in soccer, a position that involves a great deal of running relative to other positions on the pitch. “So, day in and day out, that load can then start to generate a little bit of discomfort in and around the physis or apophysis. But they may keep playing through it, which can lead to the overuse injury.”

## Sports-specific issues

Coleman said she generally sees more apophyseal injuries versus physeal injuries, especially in kids who specialize in a single sport, as their training is geared toward the same mechanics year-round.

“They often overuse [growth] areas that shouldn’t have so much continuous stress on them at that time,” she explained. “The apophyseal injuries tend to be overuse injuries because they are repeating the same actions in a single sport.” Indeed, the American Academy of Pediatric Medicine recommends against sports specialization for young athletes, citing potential adverse health effects, including musculoskeletal ones.<sup>5</sup> (See “Early athletic specialization: Misconceptions and hazards,” February 2017, page 15.)

In terms of which sports carry a higher risk for either type of lower extremity growth-plate injury, those that involve kicking top the list—soccer, martial arts, football, even dancing, according to Jennifer M. Weiss, MD, an orthopedic surgeon at Kaiser Permanente



in Los Angeles, and a spokesperson for the American Academy of Orthopaedic Surgeons.

Sports that require pivoting, jumping, and running also pose a higher risk, particularly for acute physeal injuries, Coleman noted. "Any sport where a person is competing against others to obtain one object, there's a risk for injury, whether it's because of an athlete's own poor biomechanics or a collision with another player," she explained.

A literature review pointed out that "the tolerance limits of the physis may be exceeded by the mechanical stresses of sports such as football . . . American football is the sport most often connected with acute physeal fractures," for example, a place kicker who sustains a stress injury of the distal femoral physis, or a "clipping injury" fracture of the epiphysis.<sup>6</sup> Clipping injuries occur when a player is blocked or tackled from the lateral side at knee level with the foot firmly planted.<sup>7</sup>

The repetitive physical loading required in baseball, gymnastics, and distance running may lead to apophyseal injuries, which are usually related to overuse.

"I see more of the chronic overuse injuries, but that may be because I do primary care sports. The true growth-plate injuries, the physeal injuries, they go to the ED first, and then they are more likely to be sent to orthopedics, especially the more severe types of growth plate fractures," Coleman noted.

Molony pointed out that overuse injuries in kids will manifest differently than in adults, even if they participate in the same sport. He cited Sever disease as an overuse injury that looks different based on the patient's age and stage in life. In a child, "the apophysis exists where the tendon attaches to the bone; the Achilles ten-

don attaching to the heel. So, an adult runner may develop Achilles tendinitis. In the skeletally immature population, the Achilles tendon is generally going to be fine. It's the growth center at the calcaneus where it attaches that gets irritated."

As for Osgood-Schlatter disease, Molony noted overuse that would cause infrapatellar tendinitis in the lower extremities of an adult would be more apt to cause apophysitis at the tibial tubercle in the skeletally immature athlete.

## Spotting physeal injuries

Pinpointing physeal injuries is vital, as kids will continue to mature physically so "that timing is important—the younger a child is, the sooner that bone starts to try to heal [on its own]," Weiss stated. "In a four-year-old, you probably have a week to ten days to really recognize that injury and move the growth plate back into place. With an eighteen-year-old, you might have up to two weeks because the bone is not trying to heal itself as quickly."

But, as Coleman noted earlier, most young patients who sustain an acute injury will first present to the ED or a trauma center, and it's at this first line of medical care where physeal injuries can be misdiagnosed.

A study that looked at four years of diagnostic errors in the ED of a general hospital in England found that, of 108 ankle fractures missed on x-rays, eight were later diagnosed as epiphyseal avulsion fractures.<sup>9</sup>

X-rays may not tell the whole story when it comes to diagnosing suspected physeal fractures. Molony gave the example of a young athlete presenting at urgent care or the ED with a physeal injury.

*Continued on page 18*

**REDI-  
THOTICS**™

*More Comfort. More Performance.*

**Try a pair on us!**

## PEDIATRIC **HEAT** MOLDABLE ORTHOTICS



**RIGID ORTHOTICS**



**SEMI-FLEXIBLE ORTHOTICS**

**Phone: (877)740-3668 Fax (860)417-3592 [www.Redi-Thotics.com](http://www.Redi-Thotics.com)**



iStockphoto.com 182149281

"They may get plain films, but that Salter Harris Type I fracture may be missed because that fracture line goes through the physis. On plain films, the physis is 'clear,' so there's no crack to see, so to speak. Also, it may not be gapped at all."

Without definitive imaging information, a thorough clinical exam is paramount. Practitioners should start with asking the patient, "What happened?"

"I ask for a very detailed description from the child as to the circumstances of the injury," Weiss said. "Even a four-year-old can describe what happened. I've found that if the circumstances of the injury are something they can't really remember, then the chances of it being a break are fairly low. People tend to remember whatever happened that caused a broken bone. Then I ask the parents to weigh in after I've spoken to the child."

Molony recommended the practitioner ask the patient to point to the area of maximal pain with just one finger. "Often, they will point to the bone rather than the soft tissue, but you have to pay close attention to that," he said. "Don't rely just on verbal explanation of where the pain is; ask the person to point to it directly with one finger because that helps with the accuracy. Then confirm that point of maximal tenderness through the [clinical] exam."

Coleman emphasized that practitioners need to conduct what she called a secondary survey. "Make sure to evaluate above and below the injury so you can determine if there could be another injury that isn't hurting as much as the one the patient is complaining about at the time," she noted. "Let's say the patient is complaining about knee pain—we also look at the hip, the ankle, the skin, and the general area around the injury."

Another option is to ask if the family has any footage of the incident. "At least once a week, I have a parent with an injured child who comes in and shows me the video of what happened, which is great," Weiss said. "I think it's safe to say that dancers and gymnasts always have video."

Experts also agreed it's important not to give into bias and go for the easiest or most extreme diagnosis.

"You may suspect that it's a sprain, but don't base your [clinical] evaluation on that suspicion," Coleman warned. "Just because you


don't see an obvious injury on the x-ray doesn't automatically mean the child only has a sprain."

On the other hand, "the physis isn't always injured," Molony said. "It may well be an ankle sprain or a soft tissue injury. But you want to take the time to rule out any possible physeal injuries before making a definitive diagnosis. Assume a physeal injury until you have evidence that shows otherwise."

Even if the x-ray has limited value, it's still worth obtaining, Weiss said. "If a kid comes in complaining of hip, groin, or buttock pain, I get an x-ray. I don't just chalk that up to a groin sprain or a hamstring pull because if there is avulsion fracture and it is missed, even if the treatment is not going to change, then we need to acknowledge that there is a piece of bone broken."

One way to identify a Salter Harris Type I is through a widening of the physis, Molony said, but to a practitioner who isn't familiar with a potential widening, "it can be difficult to tell on plain film whether it's widened or not."

How to handle this lack of definitive imaging data? One option would be to obtain a bilateral x-ray and compare the affected and unaffected sides, Molony suggested, though that still requires a certain degree of familiarity with the appearance of a healthy physis.

Weiss said she does not send patients with suspected physeal injuries, but inconclusive x-ray results, for MRI scans because "the MRI isn't going to change my management. If I have a child who has a nondisplaced break through the growth plate of the ankle, I'm going to treat them with a cast or a walking boot, and I'm going to do the same if it's a sprain." 

*Shalmali Pal is a freelance writer in Tucson, AZ.*

**This is the first part of a two-part series on physeal injuries. Look for part two, which will cover management and physeal issues in anterior cruciate ligament reconstruction (a procedure that itself can lead to growth disturbance) in our July issue.**

References are available at [lerpediatrics.com](http://lerpediatrics.com).



# Fuzion™ Family

greater fit, function & freedom<sup>SM</sup>



**KNOW BETTER ORTHOSES™**



## KEY BENEFITS

- Proprietary heat adjustable plastic to enhance the orthotic management programs for challenging patient profiles
- New treatment options for patients experiencing the need to:
  - Address heightened sensitivities to touch, pressure, movement and temperature
  - Decrease excessive loading of ligaments, muscles, tendons and joints
  - Provide circumferential joint and segment stabilization
- Address unresolved pressures
- Accommodate volume changes
- Optimize wearing opportunities for patients with limited acceptance of more traditional plastic designs
- Easy cleaning for daily, part-time and transitional wearing programs
- Available for both pediatric and adult patients

Fuzion resources available online at  
[www.orthomerica.com/fuzion](http://www.orthomerica.com/fuzion)

**ORTHOMERICA®**  
 877-737-8444 | [www.orthomerica.com](http://www.orthomerica.com)

# PROTOKINETICS

Leading Innovation in Gait & Balance Measurement

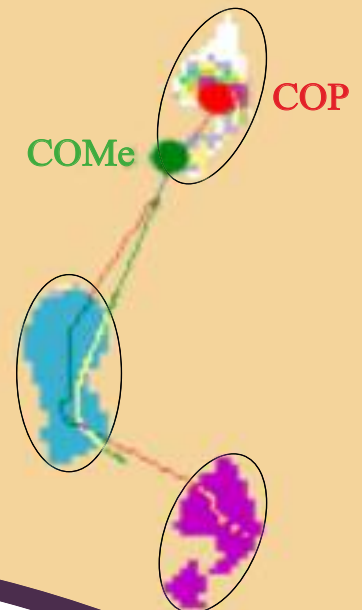
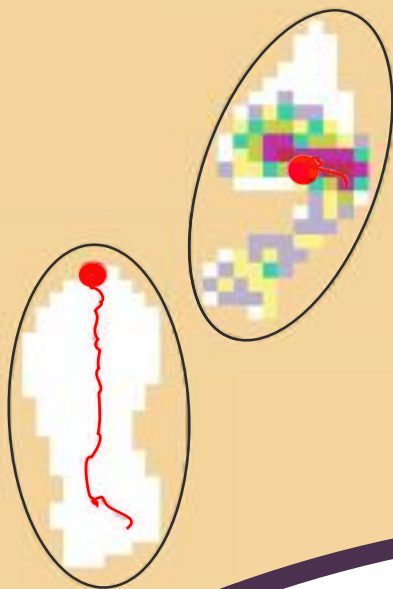
The Most Popular  
“gait mat” Technology  
In the World!



Best In Class  
Product Knowledge  
Combined with  
Amazing Customer Service

## PKMAS/Zeno

### The Gait & Balance Performance Solution



info@protokinetics.com  
610.449.4879



www.protokinetics.com  
facebook.com/protokinetics