Features

Special Pull-Out Section

Evidence Note
The Biomechanics of Ambulation after Partial Foot Amputation

Evidence Note
The Use of KAFOs and HKAFOs for Ambulation

Sponsor’s Editorial
Normalizing Shank Kinematics with Adjustable Dynamic Response™

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Supplement of *The O&P EDGE*
As I approach the last quarter of my year as president of the American Academy of Orthotists and Prosthetists (the Academy), I have concluded that in order to be successful, all the organizations representing the different aspects of our field need to work together. That in no way means that we combine as one organization, but it does mean respecting one another and recognizing the role that each organization plays. We must work to maximize what can be done in each area to better serve our members and our patients. We need to work closely with patient-advocacy groups such as the Amputee Coalition of America (ACA) with whom we share the common goal of improving the lives of those who need O&P services.

Sometimes the current relationships among the organizations in our profession remind me of Aesop’s fable, “The Father and His Sons,” in which the sons are always quarreling with one another. The father hands them each a stick and tells them to break it. Since this is easily done, the sons are puzzled about their father’s intent. The father then hands a bundle of sticks to the first son and instructs him to break it. The first son can’t break the bundle, and neither can any of his brothers. The father says to the boys, “If you are of one mind and unite to assist one another you will be like the bundle of sticks, but if you are divided among yourselves, you will be broken as easily as the individual sticks.”

In an effort to ensure that we work more closely with our sister organizations, I have begun meeting with the presidents of those organizations to see where we can support one another and work together on projects that will benefit the entire O&P profession.

While this is happening, the Academy is moving forward, and our three councils—Education Development (EDC), Professional Issues (PIC), and Research (RC)—are hard at work. The EDC’s Clinical Content Committee, led by Joanne Kanas, DPT, CPO, has planned an impressive education program, including clinical and practice management presentations, for this year’s annual meeting at the Hyatt Regency Chicago, February 24–27, 2010.

The EDC and our grant committee recently held successful One-Day Seminar Certificate Programs. The Orthotic Management of Scoliosis & Kyphosis Program, chaired by Bill Barringer, MS, CO, featured the leading experts in scoliosis management. Board member Mark Muller, MS, CPO, FAAOP, chaired the Sub-Atmospheric Suspension Systems Certificate Program, which was an impressive blend of clinical application and evidence. Both Academy One-Day Seminar Certificate Programs will be available on the Academy’s Paul E. Leimkuehler Online Learning Center (OLC).

An exciting new benefit for Academy members is the regular Literature Updates being put together by our Publications Committee and its chair, Sam Phillips, PhD, CP, FAAOP. This new addition is a great help to our members in staying current on the literature in the field.

Our scientific societies are developing a new biannual newsletter, and three of our societies are presenting at our annual meeting next month in Chicago. Each society will hold business meetings there as well. Some will have special sessions, including poster sessions, during their meetings. Board member David Gerecke, CPO, FAAOP, is working closely with our society chairs to broaden their reach and bring society members more information in their specialties.

The PIC has been very active regarding the healthcare-reform bill. The Academy works on these issues directly through its involvement with the O&P Alliance. The other members of the O&P Alliance are the National Association for the Advancement of Orthotics and Prosthetics (NAAOP), the American Board for Certification in Orthotics, Prosthetics & Pedorthics (ABC), and the American Orthotic and Prosthetic Association (AOPA).

Board member Michelle Hall, CPO, FAAOP, is working to expand the role of the Women in Orthotics & Prosthetics Committee. There is now a section on our website for this committee. In addition to its mentoring program, the committee will be highlighting the work of some of the tremendously successful women in our profession.

Former Board member Robert Brown Jr., CPO, FAAOP, has recently become chair of the Licensure Committee. He will be working to update our Licensure Toolkit and urging more states to work on attaining licensure requirements.

The Research Council, working with the Grant Committee, has recently announced the completion of the new Advanced Education & Research Training Initiative (AERTI) document, which serves as a guide to future needs and endeavors in O&P research. The Research Council is also working on the review of the Resident Directed Studies and this year will be providing programming at the Academy’s Annual Meeting in conjunction with the Orthotic and Prosthetic Education and Research Foundation (OPERF).

I want to encourage you to get involved at some level with one or more of the many great activities going on at the Academy. When I think about the great strides the Academy has made in recent years, I think about a quote from Sam Walton, “We’re all working together. That’s the secret.”

Keith M. Smith, CO, LO, FAAOP
2009–10 President

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Grant Update

Academy Grant Sponsors Education Programs at Annual Meeting

The Academy is pleased to be able to offer a number of educational programs during its 36th Annual Meeting and Scientific Symposium (Hyatt Regency Chicago, February 24–27, 2010) that are sponsored by the Academy’s grant from the U.S. Department of Education (grant number H235K080004). The funds from this grant have allowed the Academy to pursue improving the level of research in orthotics and prosthetics, create standards of practice within the profession, and increase awareness about careers in orthotics and prosthetics to the general public. All of these strategies contribute to our overarching goal of improving orthotic and prosthetic patient care for the patients you see in your offices every day.

It’s All about Outcomes

The results of the most recent Academy State of the Science Conference (SSC) on Upper Limb Prosthetic Outcome Measures will be discussed on Thursday, February 25, 2:20–3:50 p.m. This SSC included a multidisciplinary and multinational panel of subject-matter experts and was chaired by Laura A. Miller, PhD, CP, assistant professor, Rehabilitation Institute of Chicago (RIC), Northwestern University Feinberg School of Medicine; and Shawn Swanson, OTR/L, national director of Occupational Therapy, Advanced Arm Dynamics, Redondo Beach, California. Both of these experts will present at the Annual Meeting session.

During their session they will describe the research results that have been completed in the last five years toward consensus in the area of upper-limb prosthetics, identify the recommended patient assessments, and identify the work that remains to be done to further develop other important assessment tools. During the SSC, the group identified future research priorities, and those will also be addressed.

If you want more details now on the SSC, you can download a copy of the SSC Proceedings from our website at www.oandp.org. You can also order a print copy from the Academy Bookstore while you’re in Chicago or call the bookstore at 301.617.7805. Print copies are just $20 for Academy members ($40 for non-members).

Learn More from the Convenience of Your Office or Home

In addition to the published proceedings, the results of the SSC have been turned into an online education course on upper-limb prosthetic outcome measures available on the Academy’s Paul E. Leimkuehler Online Learning Center (OLC). You’ll earn 22.5 PCE credits when you complete all of the modules and take the quizzes. Visit the OLC at www.oandp.org/olc for more information or to register.

Certificate Programming at Its Best

Over the last several years, the grant has enabled the Academy to develop and present a number of its certificate programs. This year’s Orthotic Management of Scoliosis & Kyphosis seminar is the latest in this successful series of seminars in which you can earn continuing education credits and meet one of the requirements for earning the distinction of Fellow of the Academy. At this year’s Annual Meeting, three of the modules from the Scoliosis & Kyphosis program will be presented:

- Module 1: The Etiology and Natural History of Idiopathic Scoliosis—Thursday, February 25, 5:00–5:45 p.m., presented by Donald E. Katz, CO, LO, FAAOP
- Module 3: Biomechanical Considerations for Orthotic Treatment of Idiopathic Scoliosis—Friday, February 26, 4:30–5:15 p.m., presented by J. Martin Carlson, CPO, FAAOP
- Module 6: Present-Day Systems for the Orthotic Management of Scoliosis—Saturday, February 27, 7:45–8:30 a.m., presented by Keith M. Smith, CO, LO, FAAOP

You will want to take advantage of the opportunity to learn all you can from the subject-matter experts who will be presenting in Chicago.

If you have any questions about these sessions or other events taking place during the Academy’s 36th Annual Meeting and Scientific Symposium in Chicago, February 24–27, 2010, contact Kimber Nation at 202.380.3663 or e-mail knation@oandp.org
Evidence Note

The Biomechanics of Ambulation after Partial Foot Amputation

Key Points

- Partial foot amputation is the most common type of amputation in the United States and occurs nearly twice as frequently as either transtibial (below-knee) or transfemoral (above-knee) amputation.
- There is strong evidence that partial foot amputation affects multiple aspects of gait including causing a loss of power generation at the affected ankle.
- There is limited evidence to support our understanding of the influence of prosthetic and orthotic intervention. The available evidence suggests that “above ankle” devices may be better able to restore the center of pressure excursion than “below ankle” approaches.
- Methodologically strong research is required to support existing investigations and improve the depth of knowledge regarding the biomechanics of ambulation after partial foot amputation.

Scope of Review

The purpose of this Evidence Note is to facilitate access to knowledge regarding the biomechanics of ambulation after partial foot amputation (PFA) and the effect of prosthetic and orthotic interventions.

Published research that evaluated some aspect of gait in persons with PFA, with or without a prosthesis or orthosis, was considered as part of this Evidence Note. Consistent with the International Standards Organization (ISO) definition of PFA, publications describing the gait of persons with Syme’s amputation (ankle disarticulation) were not considered.

Etiology

PFA is an all-too-common sequel to advanced vascular disease, typically secondary to diabetes. Less commonly, PFA may result from trauma, limb deficiency, frostbite, or systemic disorders.

Based on data from the Vital and Health Statistics, Ambulatory and Inpatient Procedures and accounting for the increase in the population since 1996, it can be estimated that there are approximately 1.27 million Americans living with lower-limb amputation. More than 618,000 persons have a PFA, making the procedure nearly twice as common as either transtibial (below-knee) or transfemoral (above-knee) amputation. Estimates of the prevalence of limb loss in the United States for 2005 are comparable.

Descriptions of Prosthetic and Orthotic Interventions

A wide range of devices have been used by persons with PFA, including foot orthoses, toe fillers, cosmetic silicone prostheses, ankle-foot orthoses, slipper sockets, or clamshell-type prostheses. These devices are typically used with regular footwear, but on occasion may be used with “extra depth” or custom shoes. Shoe modifications, such as rocker soles, have also been used as an adjunct to prosthetic and orthotic intervention.

Given that the incidence of PFA increases exponentially after 40 years of age, almost in parallel with the incidence of diabetes, one could contend that the number of persons with PFA will increase as the number of older persons and those living with diabetes increases. Similar observations have been made about the increasing incidence of lower-limb amputation more broadly.

The vast majority of PFA involve the toes and/or metatarsophalangeal joint (76 percent) with more proximal procedures, including transmetatarsal or mid-tarsal amputation, less frequently performed (24 percent). Persons with amputation proximal to the metatarsophalangeal level experience the most significant functional deficit and are therefore likely to seek treatment from a prosthetist or orthotist.

Generally, the extensiveness of the intervention is proportional to the extent of tissue lost. Persons with amputation affecting the toes or metatarsals may use relatively simple insoles or toe fillers. These devices are usually made from various foams or silicone-type materials aimed at redistributing pressure (typically away from the end of the remaining foot) and thereby preventing skin breakdown and ulceration. By comparison, persons with amputation at the Chopart level (midtarsal disarticulation) may use a more extensive clamshell-type prosthesis incorporating a rigid laminated socket that encompasses the leg and remaining foot. As well as protecting the residuum from skin breakdown, these devices aim to improve gait by replacing the effective foot length.
Summary of the Evidence

A single systematic review describing the biomechanics of amputation after PFA was identified. This review formed the basis of the American Academy of Orthotists and Prosthetists (the Academy) Eighth State of the Science conference. The review appraised 28 publications from an uncontrolled literature search to December 2006. The review included findings from a doctoral dissertation that has since been published. The additional studies published since this review did not meet the criteria defined in the scope of this Evidence Note.

The majority of publications included in this systematic review were observational, with only a few experimental studies comparing the effect of different prosthetic and orthotic interventions on gait.

While the review concluded that there was a “high” level of evidence that PFA affects many aspects of gait (i.e., temporospatial, ankle kinematics and kinetics, as well as plantar pressures), there was little confidence in the evidence regarding how these aspects of gait are changed by PFA or prosthetic and orthotic intervention. For example, there was a “high” level of evidence that PFA had an effect on sagittal plane ankle kinematics during gait but only a “low” level of evidence that PFA changes the magnitude or timing of the dorsiflexion peak during stance or that differences exist based on amputation level.

In general, there is “insufficient” evidence regarding the efficacy of particular prosthetic and orthotic interventions because the majority of publications were observational and the few experimental studies were often inadequately designed.

The depth of our understanding of the effects of PFA and the influence of prosthetic and orthotic intervention on the biomechanics of walking has been limited by a number of consistent flaws in the design of the research. For example, amputee cohorts tended to be quite heterogeneous in terms of time since amputation, amputation level (including the number of toes amputated), age, and involvement of the contralateral lower limb. Experimental studies often failed to match study groups to control for the influence of systemic disease. This makes it difficult to know whether the differences observed between experimental conditions reflect the intervention or merely the underlying disease in one of the experimental groups.

Despite these problems, there is some limited evidence describing how persons with PFA walk and the influence of prosthetic and orthotic intervention. The following provides a brief summary of the findings of the systematic review; however, more research is needed to improve the level of confidence in these findings.

Persons with PFA walk at much the same speed as appropriately matched controls. The slower velocity often observed in persons with PFA seems to be attributable to the influence of diabetes, rather than the amputation itself.

Power generation across the affected ankle during gait is virtually negligible once the metatarsal heads have been compromised, regardless of the residual foot length or the type of prosthetic and orthotic intervention provided. Insoles, toe fillers, and slipper sockets do not allow the center of pressure (CoP) to progress beyond the end of the remaining foot until after contralateral heel contact, when weight is shifted to the unaffected limb. In contrast, clampshell-type devices often provided to persons with Chopart amputation seem to normalize the CoP excursion as did a BlueRocker ToeOff orthosis.

It has been hypothesized that the ability of a prosthesis to restore the effective foot length requires a suitably stiff forefoot capable of supporting the amputee’s body mass, a socket or anterior leg shell capable of comfortably distributing to the leg and remaining foot the interface pressures caused by loading the toe lever, and a relatively stiff connection between the foot and leg segment to help moderate the moments caused by loading the toe lever. Either a rigid ankle, a free joint with a dorsiflexion stop, or the sort of stiffness inherent in a BlueRocker ToeOff orthosis may be appropriate.

There is a moderate level of evidence that PFA causes an increase in peak forefoot pressures compared to the contralateral side. There is insufficient evidence to suggest that prosthetic and orthotic interventions have an effect on pressure distribution compared to footwear alone because only one paper directly compared various pressure-reduction interventions.

Future Research

There is a need to improve the depth of knowledge on this topic. Well-designed observational studies are needed to help answer basic questions about the gait of persons with PFA so that we can move toward well-rationalized comparative-effectiveness studies of prosthetic and orthotic interventions.

In some cases, the “low” level of evidence on this topic could be improved by independent verification of findings that are
currently based on a single, small, well-executed investigation whose evidence cannot, in isolation, be vested with great confidence.\textsuperscript{21} In other cases, consistent flaws in research design limited confidence in the findings, and researchers should consider these issues when designing future investigations.\textsuperscript{21}

Although challenging, many of the flaws in research design can be addressed with careful consideration and planning.

\textbf{Acknowledgments}

This Evidence Note was compiled by Michael Dillon, PhD, with the assistance of Stefania Fatone, PhD. This Evidence Note was made possible by the American Academy of Orthotists and Prosthetists through a grant (Award Number H235K080004) from the U.S. Department of Education. The contents do not necessarily represent the policy of the Department of Education, and you should not assume endorsement by the Federal Government. Thanks to Scott Magis for the illustrations.

\textbf{Suggested Citation}


\textbf{References}


42. Armstrong DG, Lavery LA. Plantar pressures are higher in diabetic patients following partial foot amputation. *Ostomy Wound Manage.* 1998;44:30–32.


Health Technology Description
An orthosis is defined by the International Standards Organization (ISO) as “an externally applied device used to modify the structural and functional characteristics of the neuromuscular and skeletal system.” An orthosis is defined by the International Standards Organization (ISO) as an externally applied device used to modify the structural and functional characteristics of the neuromuscular and skeletal system. Knee-ankle-foot orthoses (KAFOs) are orthoses that encompass the knee and ankle joint and the whole foot or part of the foot, while hip-knee-ankle-foot orthoses (HKAFOs) are essentially KAFOs that extend across the hip joint, connecting to a pelvic band or, when more trunk stability is required, lumbar or thoracic spinal support. KAFOs and HKAFOs account for 11 percent of practice by certified orthotists in the United States. All knee-joint components provide coronal-plane stability with varying biomechanical control in the sagittal plane. Examples include locked joints that hold the limb in full extension until manually disengaged for sitting; locked joints with variable flexion that allow for accommodation of knee-flexion contractures; single axis, offset, and polycentric joints that allow free flexion-extension; and stance-control joints that automatically lock and unlock during the stance and swing phases of gait. Although a locked KAFO is able to reliably provide stability during the stance phase of gait, it does not allow for flexion of the knee in swing, leading to compensatory actions such as vaulting, hip hiking, and circumduction that ensure clearance of the ground by the foot during swing phase. Stance-control joints attempt to address these issues by providing reliable stance-phase control while still allowing swing-phase knee flexion. Additional stability may be provided to bilateral KAFOs by the application of a medial joint that permits motion in the sagittal plane but not in the coronal or transverse plane (e.g., the Walkabout Orthosis).

Bilateral HKAFOs stabilize the lower limbs during stance in persons with paraplegia and allow swing-through gait when crutches are used. If the orthotic hip joints are mechanically linked, reciprocal gait may be achieved. Two fundamental mechanical designs of linked HKAFOs have been developed. Both designs use lateral weight shift from one limb to the other, with the added assistance of crutches or a walker, as the basis for reciprocal gait. A hip-guidance orthosis (HGO), such as the ParaWalker, consists of bilateral KAFOs linked via specially designed low-friction hip joints with flexion/extension stops and a release mechanism that allows for sitting. It has been suggested that the most important design characteristic of the HGO is its rigidity in single-limb support, which keeps the lower limbs essentially parallel in the coronal plane, providing for better ground clearance of the limb during swing. The reciprocating gait orthosis (RGO) couples motion of the two orthotic hip joints so that flexion of one hip results in extension of the other. Types of RGOs include the LSU-RGO, which utilizes two crossed-Bowden cables to couple hip motion; the advanced RGO (ARGO), which utilizes a single Bowden cable; and the isocentric RGO (IRGO) which utilizes a centrally pivoting bar and tie-rod arrangement to couple hip motion. Although HGOs and RGOs were originally designed for use on children, more recent literature has focused on their use on adults with spinal cord injury (SCI).

Scope of Review
The purpose of an Evidence Note is to provide a summary of the available evidence on a particular topic, facilitating access to knowledge. The focus of this evidence note is on custom-made orthoses intended for long-term use and not prefabricated devices, that are worn for less than a year. Orthoses whose primary function is other than to enhance ambulation, such as fracture orthoses and post-operative immobilization devices, are excluded from this Evidence Note. Given these review criteria, use of unilateral KAFOs was not well captured by this review since the literature regarding ambulation focuses primarily on persons with lower-limb paralysis who require bilateral KAFOs.

Epidemiology
The most common justification for a KAFO is the need for direct control of the knee in addition to the ankle and foot, while HKAFOs are typically used where there is bilateral lower-limb paralysis. While KAFOs can be worn unilaterally or bilaterally...
as required, use of unilateral HKAFOs is rare and limited to short-term application following hip arthroplasty to allow for protected walking. The principal impairments addressed by KAFOs are paresis or paralysis of the muscles controlling the knee joint, upper motor-neuron lesions resulting in hypertonicity (spasticity) of the lower limb, or loss of structural integrity of the hip or knee joints. A literature review of KAFOs and HKAFOs for ambulation indicated that KAFO users include children with Duchenne muscular dystrophy (DMD) and persons with a diagnosis of polio, post-polio syndrome, or stroke; while users of HKAFOs include adults with SCI or paraplegia and children with myelomeningocele.

**Clinical Effectiveness**

Three systematic reviews regarding the use of KAFOs and HKAFOs for ambulation were identified.

As part of the Spinal Cord Injury Rehabilitation Evidence project, Lam et al. reviewed 14 studies that reported the effects of gait training with KAFOs and HKAFOs in people with complete and incomplete SCI, and seven studies that examined the combined effect of RGOs and functional electrical stimulation (FES) on functional ambulation in people with complete SCI. They concluded that limited evidence suggests the benefits of orthotic management alone on functional ambulation are primarily for people with incomplete spinal lesions. The advantages of orthotic management are primarily the general health and well-being benefits related to standing and ambulating short distances in the home or indoor settings. There is limited evidence that a combined approach of orthoses and FES results in additional benefit to functional ambulation in paraplegic patients with complete SCI.

Ijzerman et al. reviewed 12 comparative trials of HKAFOs with and without FES for adults with complete thoracic lesions and reported that all the studies were internally invalid due to inadequate study design (simple within-subject comparisons without randomization of orthosis testing order) and lack of statistical power (small, heterogenous study populations).

Bakker et al. reviewed nine controlled and uncontrolled clinical trials and case studies regarding intervention with KAFOs for children with DMD. They also noted that the scientific strength of the reviewed studies was poor but nevertheless concluded that use of KAFOs in the management of DMD can prolong assisted walking and standing. It remained uncertain whether KAFOs prolong “functional walking” because most studies were vague on what constitutes functional walking.

In 2006, the American Academy of Orthotists and Prosthetists (the Academy) held a state of the science conference on the use of KAFOs and HKAFOs to assist with ambulation (SSC7). The literature review for this meeting identified two randomized control trials and included 27 cross-sectional studies published between 1995 and 2004. The review concluded that though a reasonable amount of literature had been written regarding KAFOs and HKAFOs, the level of evidence regarding their use for ambulation was generally low. There was some evidence that use of HKAFOs diminishes with time in both adults and children with paraplegia and that when orthoses are used, they are used mostly for therapeutic purposes. There was also some evidence that walking speed is slow and energy cost high in people with paraplegia regardless of orthotic device used. clinicians

There are as yet no reviews regarding stance-control orthoses (SCOs). To date, there have been seven cross-sectional studies, ten case studies, and two technical notes. Three have evaluated gait with the Horton’s Stance Control Orthotic Knee Joint (SCOKJ), six describe development and evaluation of the dynamic knee-stance system (DKBS), and two describe development and application of an electromechanical stance-control KAFO (SCKAFO). A single case study describes attempts to combine stance-control joints with an RGO. The majority of these studies have been in able-bodied persons or persons with unilateral limb weakness resulting from conditions such as polio. Preliminary studies suggest that providing stance control may decrease compensatory maneuvers (vaulting, hip hiking) and energy expenditure compared to walking with a locked knee.

**Safety**

It is recommended that qualified orthotists should contribute to the assessment and prescription of orthoses and be specifically responsible for manufacture and delivery of orthotic devices. An orthotist is an allied health professional who is specifically trained and educated to provide or manage the provision of a custom-designed, fabricated, modified, and fitted external orthosis to a patient. Practitioners who successfully complete the education, experience, and examination requirements prescribed by an accrediting body become certified orthotists. Certification indicates that the orthotist has met established standards and has the qualifications required to render orthotic services. A certified orthotist is the best person to ensure safe provision and use of a KAFO or HKAFO.

**Economic Implications**

No published studies examining the cost effectiveness of KAFOs and HKAFOs were identified. A review of Medicare payment data for 2007 shows that the allowable base rate of a single custom-fabricated KAFO ranged from $734–$3,289, while the allowable cost for an RGO was approximately $8,306 using the suggested coding for an ARGO as an example.

**Future Research**

Designing adequate studies to investigate the effect of KAFOs and HKAFOs on ambulation is challenging due to the heterogeneous populations that use these devices and the heterogeneity within each population. It has been recommended that randomized crossover interrupted time
series trials be used to improve the internal validity and statistical power of future research regarding KAFOs and HKAFOs for ambulation. Furthermore, Fatone indicated that the population being evaluated (diagnosis, time since injury, lesion level, whether a lesion is complete or not, residual muscle function, prior experience with orthosis, training provided, type of gait pattern used) and the orthosis being used must be adequately described in order for study data to be interpreted and the information generalized or compared between studies.

The following primary research priorities regarding use of KAFOs and HKAFOs for ambulation were identified by participants of SSC7:

- Identify and/or develop standardized subjective and objective outcome measures.
- Investigate the short- and long-term effects of KAFO and HKAFO use on the neuromusculoskeletal system.
- Research application of SCOs.
- Define the mechanical loading conditions on KAFO and HKAFO devices to guide orthotic design and application.
- Determine the short- and long-term effects of physical therapy intervention, including gait training, on outcome and acceptance of KAFOs and HKAFOs.
- Measure the impact of pharmacological management on successful use of KAFOs and HKAFOs in persons with severe spasticity.

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This Evidence Note was compiled by Stefania Fatone, PhD. This Evidence Note was made possible by the Academy through a grant (Award Number H235K080004) from the U.S. Department of Education. The contents do not necessarily represent the policy of the Department of Education, and you should not assume endorsement by the federal government. Thanks to Kathy Dodson, American Orthotic & Prosthetic Association (AOPA), for providing the 2007 Medicare payment data and Scott Magis for the drawings.

Suggested Citation

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Normalizing Shank Kinematics with ADR™

The term “shank” is often used in gait labs and refers to the lower part of the limb between the knee and the ankle. Normalizing shank kinematics (shank motion) is critical to optimizing gait function. Normalizing the kinematics of the shank throughout gait using orthotic management has attracted substantial attention, particularly due to the work done by Owen and Bowers at The University of Strathclyde, Glasgow, Scotland. The concept of shank kinematics has also been referred to as “tibial advancement in gait” by Perry. In protocol development for orthotic management of the limb during stance phase (when the foot is on the ground and emphasis is on optimizing tibial progression over the foot in the sagittal plane), orthotists may ask, “What type of AFO allows us the ability to normalize shank kinematics or tibial advancement?”

Owen points out, “Children with pathological gait have abnormal shank kinematics. Normalizing shank kinematics produces the best chance of achieving optimum thigh and trunk kinematics and knee and hip kinetics.” The Strathclyde Approach focuses on the shank angle throughout stance relative to the floor. If we control the shank angle, or the kinematic, we then influence the kinetics, or forces associated with gait, a concept offering much orthotic potential to help normalize pathological gait with orthotic management.

The ‘Tuning’ Approach: Angle of the Shank Relative to the Floor

The Strathclyde Approach uses the term Ankle-Foot-Orthosis-Footwear-Combination (AFOFC), emphasizing both the AFO and the footwear. “Tuning”—adjusting the heel-sole differential of the shoe to affect shank kinematics—the AFOFC relative to the vertical, allows the practitioner to control shank kinematics. Manipulating kinematics results in influencing kinetics. This approach uses shoe wedges and modifications to manipulate the angles of the shank in the AFOFC. An AFOFC design algorithm is currently being used in gait labs. For example, a patient presenting with a fixed equinus contracture or knee-flexed position may be fitted with a solid AFO set in plantarflexion with a shoe wedge to promote an inclined shank at midstance.

The ‘Traditional’ Approach

A variety of AFO designs have emerged in efforts to produce the best solution or the most effective outcome. For instance, a patient who exhibits significant weakness would traditionally be fit with a more rigid design with stiffer trim lines. For less control, a more flexible design would be chosen. Due to the strength variance, some patients may receive a hinged design that allows, assists, or stops certain motions while others receive a solid design that stops most motion in the sagittal plane of the tibia over the foot. Shoe wedges or lifts to augment the final tibial angle to the ground may be implemented. Currently, there is no set algorithm for use with the traditional approach, and there is much art and variation in the traditional approach. The authors suggest more science is needed in this area.

The Goal of Pediatric AFOs

The goal of pediatric AFOs is to provide improved function while still maintaining the priorities of normal gait. Gage addresses gait priorities as (1) stability in stance; (2) clearance in swing; (3) preposition of the foot at initial contact; (4) adequate step length; and (5) energy conservation. Note that the first priority, according to Gage, is normalizing shank kinematics.

Traditional AFO Design Challenges

Gage points out some challenges with traditional AFO designs. A leaf-spring AFO, for example, can control mild equinus and/or valgus positioning during swing and may position the foot during terminal swing for initial contact. However, this more flexible design may not control more significant equinus. A rigid AFO or an AFO with a plantarflexion block may control stance phase deformities such as varus, valgus, or equinus, but the rigidity can be counterproductive in terminal stance, not allowing plantarflexion and consequently blocking acceleration for third rocker. Hinged AFOs with plantarflexion stops and free dorsiflexion may promote function in children because of the less restrained design but may encourage crouch gait in the long term.

The Ideal Orthesis

Gage states that the ideal orthosis is “a device that would control the position of the foot in swing phase, initial contact and loading response, but leave the ankle completely unencumbered during midstance and terminal stance.”

Development of Adjustable Dynamic Response (ADR)

Adjustable Dynamic Response™ (ADR)™ technology utilizes the elements of Gage’s ideal orthosis, in conjunction with the importance of normalizing shank kinematics as demonstrated by the Strathclyde Approach. This technology provides stabilized range of motion (ROM), thus limiting compromises often associated with traditional orthoses. ADR technology provides adjustable muscle augmentation, stance stability, smooth rollover, and swing clearance.
ADR has attracted increasing attention since 2004 when Ultraflex® introduced UltraSafeStep™ knee and ankle components for management of adult pathological gait such as in post-stroke and post-polio cases. ADR utilizes elastomer technology to dampen or restrain ROM during gait, resisting motion rather than completely stopping it.

Introduced in May of 2009, UltraSafeGait™, the pediatric ADR version of the UltraSafeStep is specifically sized and designed for patients weighing 110 lb. (50kg) or less. The anterior and posterior elastomer channels (Figure 1) allow for 140 in./lb. of torque restraint per channel. This amount of torque restraint is capable of augmenting the eccentric work of the tibia and the gastroc-soleus during stance. ADR elastomer technology, compared to spring technology that offers 15 –18 in./lb. of torque restraint per channel, is in a class of its own.

UltrasafeGait ADR technology provides both stability and motion in an AFO component by adjusting the component for increased or decreased resistance during observational gait analysis in the clinic setting. In the field, the clinician can fine-tune first, second, and third rocker in real time, influencing shank kinematics with simple component adjustments without removing the AFO. For example, a patient who has a crouched gait pattern could have dorsiflexion resistance increased in the anterior channel as ROM of the knee is increased. Or, a patient who hyperextends the knee could have the resistance increased in the posterior channel to decrease this tendency. Opposed to “tuning” a solid AFO with heel wedges to control shank kinematics, ADR allows clinicians to control shank kinematics by providing adjustable resistance within a component.

Clinical Example: Managing Multiple Orthotic Goals
Our patient, age 8, was born with spina bifida, GMFCS level III; he is non-verbal but enjoys swimming, T-ball, and playing video games. He underwent two separate surgeries to remove spinal tumors at the ages of four and seven. He presents with significant lower-limb spasticity, causing ROM deficits, gross lower-limb weakness, and significant crouch during gait. The patient began receiving orthotic management at age 1. Past orthotic management consisted of primarily ground-reaction AFOs, either solid-ankle designs set at 90 degrees or hinged designs allowing the angle to be locked or set in a fixed position to accommodate his hamstring tightness.

Goal 1: Improving ROM
Currently, he uses an Ultraflex dynamic resting stretching knee orthosis for his right side to address his popliteal angle, which measured -35 degree R2 prior to intervention. At the three-month follow-up visit, he progressed to a -20 degree R2 popliteal angle, demonstrating a 15-degree increase in knee ROM. He wears his stretching knee orthosis at night. Average wear time is 8–10 hours per day at a tension setting of five. Both measurements were taken prior to his receiving botulinum toxin type A, which he receives every three months.

Goal 2: Providing Stability in Stance while Normalizing Shank Kinematics
The patient also uses bilateral floor-reaction style ADR AFOs to improve stability and control crouch gait. The ADR ankle joints were initially set with resistance from the anterior channel to decrease the crouched-gait tendency. As the forefoot is loaded, the ADR joints allow for adjustable resistance into dorsiflexion. As knee ROM has increased, his orthotist has increased the resistance in this anterior channel, which has lead to a reduction in the crouch pattern (Figures 2a and 2b). Instead of being in a fixed-ankle position, the ADR AFOs allow an adjustable ankle-dorsiflexion resistance. As the patient gains knee ROM, the resistance can be increased at the ankle to create an improved knee extension/ankle plantarflexion couple.

Future Research
A prospective study examining the efficiency of the UltraSafeGait ankle-joint system with cerebral palsy patients in treating crouch-gait patterns and equinus with knee hyperextension in the sagittal plane is currently under way. Future research looks to develop outcome measures to increase functional ambulation for the patient with crouch-gait patterns or equinus with knee hyperextension, focusing on resistance, not limitations.

Clinical Significance
ADR technology is a tool to provide dynamic resistance to motion and adjust shank kinematics in a clinical setting. A significant clinical orthotic advance, it allows customized solutions to unique individual patient presentation and pathologies.

References and author’s biographies may be found online at www.oandp.org
Editor’s note: An expanded version of this article may be found at www.oandp.org
ULTRAFLEX ADR™ GIVES YOU AN EDGE WHEN YOU STEP INTO CLINIC AND GIVES PATIENTS AN EDGE WHEN THEY STEP OUT

No other orthotic technology is like Ultraflex’s Adjustable Dynamic Response™ (ADR™) when managing gait dysfunction.

It is the only functional bracing solution with resistance or dampening effects that are truly adjustable in real time while being worn by the patient. Patient-specific deficits as measured by clinical assessment values concerning range, strength, first, second, and third rockers can be immediately compensated for by adjustment of the ADR™ component technology.

The ADR™ joint provides muscle augmentation, unrestricted motion when desired, customized stability in stance, a smooth rollover, and clearance in swing.

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For adult solutions - UltraSafeStep™ for post-stroke, post-polio, crouch gait, drop foot, and foot slap

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