THE IMPORTANCE OF BEING EARNEST ABOUT SHANK AND THIGH KINEMATICS ESPECIALLY WHEN DESIGNING, ALIGNING AND TUNING ANKLE-FOOT ORTHOSIS FOOTWEAR COMBINATIONS

PRE-SESSION INFORMATION PACK

Presenters

Deborah Gaebler-Spira MD  Professor of Pediatrics and Physical Medicine and Rehabilitation, Rehabilitation Institute of Chicago, Chicago, IL
Elaine Owen MSc SRP MCSP  Clinical Specialist Physiotherapist, Child Development Centre, Bangor, UK
Stephania Fatone PhD BPO(Hons)  Research Associate Professor, Dept of Physical Medicine & Rehabilitation, Northwestern University, Chicago, IL
Donald McGovern CPO FAAOP  Orthotist and Prosthetist, Rehabilitation Institute of Chicago, Chicago, IL

Suggested Pre-Reading


Additional handouts and information, including full reference lists, will be distributed at the session. This will include a CD that will include:
Forms for clinical use
Coloured poster versions of algorithms;
Designing, Aligning and Tuning AFO-Footwear Combinations
Determining the sagittal angle of the ankle in an AFO
INTRODUCTION TO INTERVENTIONS WITH AFO FOOTWEAR COMBINATIONS
REVIEW OF ICF MODEL, HOW AFOFCs HAVE THE POTENTIAL TO IMPROVE ALL ASPECTS OF ICF

DR. DEBORAH GAEBLER-SPIRA

The primary outcome measure of any study should directly relate to the hypothesized benefit of the intervention and the measures chosen should be reliable, valid and relevant. There is increasing interest in finding out which interventions improve all aspects of the ICF; activities and participation as well as the impairment, at the body function and structure level.

A recent ISPO Consensus Conference (2009) made several conclusions and recommendations on orthotic interventions in Cerebral Palsy, which also have wider relevance.

- Dialogue between the orthotist and the team is essential, when deciding on treatment goals and the biomechanical requirements to achieve the goals.
- The role of the orthotist is to formulate the design, fit, align, deliver and review the orthosis which will in theory, achieve the biomechanical requirements desired by the team.
- Adherence is likely to be higher when there is clear agreement between the physiotherapist and orthotist regarding usage, and the family understands the rationale for the prescription.
- When an orthosis is prescribed consideration must be given as to when and for how long it must be worn. The optimum duration of use and the occurrence of side effects.
- For ambulant children available evidence from gait lab studies suggests that an AFO that prevent plantarflexion can improve gait efficiency, temporalspatial parameters and ankle kinematics.
- The indirect effects of AFOs on the kinematics and kinetics of knee and hip joints have been demonstrated; these can be optimised by tuning the AFO.
- AFOs reduce energy costs of walking but it is as yet unclear how they influence phasic activity of gait, muscle length, muscle strength, how the assessment of AFOs in the gait laboratory predict the child's mobility and gait efficiency in their usual environments.

ELAINE OWEN

The ISPO review of orthotic interventions remarked that many studies provided inadequate information on the orthosis being investigated and only rarely did papers provide adequate information on the footwear being used with orthoses. This has also been commented on in reviews by Owen (MSc 2004) and Ridgewell (2010).

When drug interventions are prescribed there are three vital components to the prescription: the name of drug, the dosage of the drug, the frequency of administration of the drug. When orthotic interventions are prescribed all three components of the prescription should also be fulfilled:

- The name of the orthotic intervention ............................................AFO Footwear Combination
- The dosage of the orthotic intervention...................................The triplanar design of the AFO and Footwear
- The frequency of administration of the orthotic intervention.........When and how long to use the AFO

In order to answer the question as to the dosage and the frequency of administration required for the orthotic intervention to be successful, we have to be clear about the orthotic aims and the desired outcomes that the clinicians, the patient, their family and carers have for the intervention. Also, how the amount of usage, required to achieve the outcomes, can acceptably be integrated into the lifestyle of the patient, family and carers. Prescribing an AFO-FC that is well matched to the patients needs and desired outcomes is essential (Harlaar et al 2010). The aims and the intended outcomes for the orthotic intervention relate to many aspects of the ICF.

Body Functions - the physiological functions of the body systems
Body Structures - the anatomical parts of the body such as organs, limbs and their components
Activity - the execution of a task or action by an individual
Participation - involvement in a life situation

Recent Developments in Healthcare for Cerebral Palsy: ISPO. Free download available from www.ispoint.org
<table>
<thead>
<tr>
<th>SKELETAL STRUCTURE</th>
<th>MUSCULOTENDINOUS UNITS</th>
<th>DEVELOPMENTAL MATURATION MOTOR LEARNING</th>
<th>FUNCTIONAL &amp; OTHER OBJECTIVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>BONES JOINTS LIGAMENTS</td>
<td>BODY STRUCTURES &amp; FUNCTION</td>
<td>BODY STRUCTURES &amp; FUNCTION ACTIVITIES</td>
<td>BODY STRUCTURES &amp; FUNCTION ACTIVITIES &amp; PARTICIPATION</td>
</tr>
<tr>
<td>SEGMENT &amp; JOINT KINEMATICS STANDING &amp; GAIT</td>
<td>BUSINESS &amp; OTHER OBJECTIVES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LENGTH</td>
<td>STIFFNESS (TONE)</td>
<td>KINETICS &amp; MOTOR LEARNING STANDING, FIRST STEPS, GAIT</td>
<td></td>
</tr>
<tr>
<td>Obtain/maintain correct length</td>
<td>Neural</td>
<td>Obtaining normal developmental order of ( \text{M} ) kinematics- learn to 1st couple shank and foot, then prepare shank and thigh.</td>
<td></td>
</tr>
<tr>
<td>Obtain/maintain the correct length of muscle to tendon ratio</td>
<td>Non Neural</td>
<td>Obtain normal developmental order of segment kinematics:</td>
<td></td>
</tr>
<tr>
<td>Neural Components:</td>
<td>Elastic</td>
<td>Prevent/reduce uncontrolled generation of abnormal internal and external moments when learning to stand, step and walk.</td>
<td></td>
</tr>
<tr>
<td>Spasticity</td>
<td>Plastic</td>
<td>Obtain/maintain controlled rates of generation of normal/optimal internal and external moments.</td>
<td></td>
</tr>
<tr>
<td>Dystonia</td>
<td>Viscous</td>
<td>Facilitate motor learning, from repetition of the generation of normal kinematics and kinetics in standing and gait.</td>
<td></td>
</tr>
<tr>
<td>Tonic Reflexes</td>
<td>Contractile</td>
<td>Provide correct postural feedback.</td>
<td></td>
</tr>
<tr>
<td>LIGAMENTS</td>
<td>Structural Shortening</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prevent ligamentous laxity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduce ligamentous laxity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stabilise ligamentous laxity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prevent ligamentous shortening</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduce ligamentous shortening</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintain optimal ligamentous length</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normalise/optimise appropriate stretching of the joints during the gait cycle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JOINTS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optimise joint alignment appropriate for age</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prevent joint deformity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduce joint deformity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stabilise joint deformity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limit range of motion of a joint</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prevent excessive motion of a joint</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase range of motion of a joint</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LIGAMENTS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prevent ligamentous laxity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduce ligamentous laxity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stabilise ligamentous laxity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prevent ligamentous shortening</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduce ligamentous shortening</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintain optimal ligamentous length</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normalise/optimise appropriate stretching of the joints during the gait cycle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LENGTH</td>
<td>STIFFNESS (TONE)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OBTAIN/Maintain correct length</td>
<td>Neural</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obtain/maintain the correct length of muscle to tendon ratio</td>
<td>Non Neural</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OBTAIN/Maintain optimal “extensibilité” of muscle belly</td>
<td>Neural Components:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normalise lengthening and shortening of MTUs in gait cycle</td>
<td>Non Neural Components:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Elastic</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plastic</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Viscous</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Contractile</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Structural Shortening</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STRENGTH</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obtain/Maintain as near normal strength as possible</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximise use of muscle strength during gait cycle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COMPENSATE for weak muscle actions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SELECTIVITY &amp; TIMING</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obtain/Maintain optimal selectivity and timing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FUNCTIONAL &amp; OTHER OBJECTIVES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHANGING &amp; MAINTAINING BODY POSITION</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WALKING AND MOVING</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SITTING &amp; UPPER LIMB</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Observe/maintain/improve sitting balance;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>trunk posture in sitting; arm and hand function in sitting &amp; standing.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>STANDING</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normalise/optimise the kinematics of the segments and joints, and the kinetics (forces and moments).</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Obtain/maintain/improve standing balance and ability to shift CoM.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHANGE POSITION/TRANSFERS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pull to stand; Kneel to stand; Sit to stand; Stand to squat; Bending down; Small steps; Transfers; Stairs.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WALKING &amp; GAIT</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normalise / optimise the kinematics of the segments and joints, and the kinetics (forces, moments and powers) of walking and gait.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improve spatiotemporal measures of gait: velocity; cadence; step/stride length; distance.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maintain/improve gait efficiency/ energy expenditure.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OTHER</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain reduction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduce/redistribute the load on tissues so as to protect tissues or promote healing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cosmesis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ride a bicycle</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ALIGNMENT OF SEGMENTS AND JOINTS

DEFINITION OF THE ALIGNMENT OF A JOINT The spatial relationship between the skeletal segments which comprise the joint (International Standards Organisation ISO 855:2003)

DEFINITION OF THE ANGLE OF THE ANKLE IN AN AFO (AA-AFO) The angle of the line of the shank relative to the line of the foot in the AFO. Described in degrees of plantarflexion, dorsiflexion or plantigrade.


The alignment of segments is most usefully measured relative to the horizontal or the vertical. The angle between the segment and the vertical is measured in degrees and described in degrees of incline or recline from the vertical. Observe the illustration of the movement and alignment of the segments relative to the vertical during the gait cycle (Winter 1990). The thigh and shank move from a reclined to an inclined position, passing through vertical. There is no place in the gait cycle when both the shank and thigh are vertical. The foot moves from an inclined to reclined position, passing through horizontal.

There is currently no agreed nomenclature for the angle of a segment relative to the vertical by the ISO. The current most commonly used nomenclature is Segment to Vertical Angle e.g. ‘Shank to Vertical Angle’. ‘Shank Angle to Floor’ also appears in the literature. They both describe the same angle.

DEFINITION OF THE SEGMENT TO VERTICAL ANGLE
The angle of the segment relative to the vertical, measured in the sagittal plane. The angle is described as inclined if the segment is leaning forward from the vertical and reclined if leaning backward from the vertical. It is described in degrees from the vertical, vertical being 0 degrees.

The Segment to Vertical Angle can be measured in standing, during a gait cycle or other activities. It can be measured when barefoot, in footwear or in an ‘AFO-Footwear Combination’.

DEFINITION OF THE SHANK TO VERTICAL ANGLE OF AFO-FOOTWEAR COMBINATION
The angle of the line of the shank relative to the vertical when standing in an AFO-FC with the weight equally distributed between heel and toe, measured in the sagittal plane. The angle is described as inclined if the segment is inclined/leaning forward from the vertical and reclined if reclined/leaning backward from the vertical. It is described in degrees from the vertical, vertical being 0 degrees.

Shank to Vertical Angle is independent of the Ankle Angle in an AFO

BIOMECHANICAL OPTIMISATION AND TUNING OF AFO-FCs

The words ‘optimising’, ‘biomechanical optimisation’ and ‘tuning’ have all been used to describe the process of selecting the optimum design of an AFO-FC. ‘Biomechanical optimisation’ is best used to describe the whole process of designing, aligning and tuning the AFO-FC. Tuning is best reserved for the process of using gait trials to adjust the design and alignment of the AFO and Footwear. Adjustments are made in order to optimise the kinematics and kinetics of ‘midstance’ and the ‘entrances’ and ‘exits’ from midstance. By adjustments to the AFO and/or footwear segment and joint kinematics and kinetics can be normalised or optimised. Normalising shank kinematics is key to succeeding.

HOW SHOULD WE DEFINE THE ROCKERS OF GAIT AND ARE THERE THREE OR FOUR?
Owen E, Child Development Centre, Bangor, UK

SUMMARY
A three-event ankle model of the rockers in gait is inadequate. A four-event model is preferable.

CONCLUSION
Definitions of four rockers are proposed: The mechanisms of the ankle and foot that produce shank kinematic during stance phase of the gait cycle (GC); First rocker during loading response (LR), heel is the pivot, movement at the ankle joint; Second rocker during mid-stance (MST), ankle is the pivot, movement at the ankle joint; Third rocker during terminal stance (TST), forefoot is the pivot, movement at the metatarsal-phalangeal joints; Fourth rocker during pre-swing (PSW), forefoot is the pivot, movement at the metatarsal-phalangeal and ankle joints.

INTRODUCTION
Perry first described the three rockers of gait, ascribing them to three subdivisions of the GC; ‘Initial/first rocker’ in LR, ‘mid-stance rocker’ in MST and ‘terminal rocker’ in TST.¹ She later renamed the rockers, according to the pivot of each rocker, ‘heel rocker’ during LR, ‘ankle rocker’ during MST and ‘forefoot rocker’ during TST and extended the description of the forefoot rocker to include PSW.² She attributes the purpose of the rockers to production of tibial advancement during stance, an essential element in forward progression. Perry has renamed the forefoot rocker in PSW as ‘toe-rocker’.³ Perry’s three rockers have been reinterpreted as solely relating to ankle kinematic and they have been renamed ‘first, second and third ankle rockers’, first involving plantarflexion during LR, second involving dorsiflexion, and third involving plantarflexion or movement from dorsiflexion towards plantarflexion, with varying interpretations of the division between second and third rockers.

METHOD AND RESULT
Tabulation of kinematic data by subdivisions of the GC reveals four events and three pivots producing the normal shank kinematic of stance.

<table>
<thead>
<tr>
<th>PROPOSED NAME</th>
<th>LR</th>
<th>MST</th>
<th>TST</th>
<th>PSW</th>
</tr>
</thead>
<tbody>
<tr>
<td>PIVOT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Joint producing tibial advancement</td>
<td>Heel</td>
<td>Ankle</td>
<td>Forefoot / MTPJs</td>
<td>Forefoot / toes</td>
</tr>
<tr>
<td>ANKLE JOINT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plantigrade to 10° Plantarflex</td>
<td>10° Plantarflex to 10° Dorsiflex</td>
<td>Virtually locked in Dorsiflex 10-12.7°</td>
<td>7° Dorsiflex to 20° Plantarflex</td>
<td></td>
</tr>
<tr>
<td>MTPJs</td>
<td>Dorsiflex 25° to 0°</td>
<td>0° to 0°</td>
<td>0° to Dorsiflex 25°</td>
<td>Dorsiflex 25°-55°</td>
</tr>
<tr>
<td>SHANK KINEMATIC degrees relative to vertical</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25° to 10° Recline</td>
<td>10° Recline to 10° Incline</td>
<td>10° to 25° Incline</td>
<td>25° to 50° Incline</td>
<td></td>
</tr>
<tr>
<td>FOOT KINEMATIC</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25° Incline to Horizontal</td>
<td>Horizontal</td>
<td>Horizontal to 20° Recline</td>
<td>20° Recline to 60° Recline</td>
<td></td>
</tr>
</tbody>
</table>

DISCUSSION
Confining interpretation of the rockers to ankle kinematic does not recognise: 1) The original purpose of describing the rockers; to describe the pivot mechanisms by which normal shank kinematic is produced during stance. 2) The original differentiation between second and third rocker; heel rise, at 30% GC, at the start of TST, the pivot transferring from the ankle to the forefoot. More recent descriptions differentiate these rockers by the point at which the ankle starts to move towards plantarflexion, or the end of TST, neither of which coincide with the start of heel rise. 3) Four events of ankle kinematic in stance, rather than three. A four event model recognises that the ankle is not in motion throughout stance. During TST, the ankle is ‘virtually locked’, in dorsiflexion.¹ ² The movement that advances the shank occurs at the metatarsal-phalangeal joints. The stiffness of the ankle in TST is essential for heel rise and the ability to achieve maximum knee extension at 40% GC, maximum hip extension at 50% GC.¹ ² These omissions may lead to inappropriate or suboptimal interventions.

REFERENCES
HOW SHOULD WE DEFINE THE ROCKERS OF GAIT AND ARE THERE THREE OR FOUR?

Normal shank kinematics produced by the 4 rockers of gait

1st Rocker 2nd Rocker 3rd Rocker 3rd Rocker

Terminal Stance Preswing

First rocker in loading response using ankle movement
Pivot at heel

Second rocker in midstance using ankle movement
Pivot at ankle

Third rocker in terminal stance using MTPJ movement
Quasi-stiffness of ankle joint in dorsiflexion

Third rocker in preswing using MTPJ movement

A CLINICAL ALGORITHM FOR THE DESIGN AND TUNING OF ANKLE-FOOT ORTHOSIS FOOTWEAR COMBINATIONS (AFOFCs) BASED ON SHANK KINEMATICS
Owen E, MSc MCSP. Child Development Centre, Bangor, North Wales, UK. LL57 2EE.

SUMMARY
Eight years experience of designing and tuning AFOFCs for a population of children with cerebral palsy, spina bifida and other conditions (n=141) on the ORLAU Transportable Video Vector Generator Gait Laboratory, which provides combined kinematic and kinetic analysis, has enabled the formulation of an algorithm which will facilitate the design and kinetic and/or kinematic tuning of AFOFCs.

REFERENCES
PROPOSED CLINICAL ALGORITHM FOR DECIDING THE SAGITTAL ANGLE OF THE ANKLE IN AN ANKLE-FOOT ORTHOSIS FOOTWEAR COMBINATION

Owen E, MSc, MCSP Child Development Centre, Bangor, North Wales, UK. LL57 2EE.

INTRODUCTION
Gastrocnemius (GN) is a tri-jointed musculotendinous unit (MTU) crossing the knee, ankle and subtalar joint. It reaches its maximal length twice in the gait cycle (GC). At initial contact, the knee is extended, the ankle plantigrade, the subtalar joint supinated and the MTU is lengthening passively. At 40% GC in terminal stance (TST), the knee reaches maximal stance extension, the ankle is in some dorsiflexion, the subtalar joint neutral and the MTU is lengthening actively. Setting the Angle of the Ankle in the AFO (AA-AFO) without regard to the tri-jointed requirements of the GN can result in insufficient length being available to allow knee extension during the GC. In addition, an overstretched GN in TST will reduce the possibility of MTU force production. The lever arm ratio between the ankle and the knee at 40% GC is 2:3, so small changes in the ankle angle are amplified at the knee. The Shank Angle to Floor (SAF) measure of an AFO-Footwear Combination is the prime determinant of gait rather than the AA-AFO. An appropriate SAF for normal gait can be achieved with a dorsiflexed, plantigrade or plantarflexed AA-AFO. The normal range of GN length in children, measured with knee extended and subtalar neutral, diminishes with age. At 16yrs, 64% of feet only reach plantigrade and 13% only reach 5° plantarflexion. The use of a variety of angles of AA-AFO is advantageous and the use of plantarflexion may be essential. Using a plantarflexed AA-AFO does not necessarily lead to MTU shortening and may increase MTU length.

REFERENCES

---

<table>
<thead>
<tr>
<th>Intervention</th>
<th>CLINICAL MEASUREMENT OF GASTROCNEMIUS LENGTH *</th>
<th>Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>YES</td>
<td>PLANTARFLEXED</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>PLANIGRADE</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DORSIFLEXED</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Is dorsiflexion fixed?</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>Intervention planned to increase range?</td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td>Can measured angle be sustained</td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td>without excessive pressure/discomfort?</td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td>Reduce ankle angle to a more plantarflexed</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>angle</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Would angle promote excessive pronation or</td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td>supination?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Additional strategies possible to negate or</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>minimise risk?</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Accept risk of loss of musculotendinous unit</td>
<td>YES</td>
</tr>
<tr>
<td></td>
<td>length OR Adjust ankle angle to a less</td>
<td></td>
</tr>
<tr>
<td></td>
<td>plantarflexed, a plantigrade, or a</td>
<td>NO</td>
</tr>
<tr>
<td></td>
<td>dorsiflexed position, and accept resultant</td>
<td></td>
</tr>
<tr>
<td></td>
<td>excessive pronation, supination or poor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>knee extension (not recommended)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>USE THE RESULTANT ANGLE FOR AA-AFO</td>
<td></td>
</tr>
</tbody>
</table>

* Note about measurement
Position to measure gastrocnemius length: Knee extended, foot dorsiflexed, foot in position of supination, neutral or pronation depending on which is associated with the least range. The supinated foot position will therefore be used for feet that escape into pronation and the neutral or pronated position will be used for feet that escape into supination.
SHANK ANGLE TO FLOOR MEASURES OF TUNED ‘ANKLE-FOOT ORTHOSIS FOOTWEAR COMBINATIONS’ USED WITH CHILDREN WITH CEREBRAL PALSY, SPINA BIFIDA AND OTHER CONDITIONS.

Owen, E. MCSP Child Development Centre, Bangor, Gwynedd, North Wales, UK, LL57 2EE.

INTRODUCTION
The footwear that is worn with an AFO is integral in determining the overall biomechanical control provided so they have been described as an AFO-Footwear Combination (AFOFC) (Meadows 1984). To replicate an AFOFC, descriptions in all 3 cardinal planes for all the features of the AFO and the footwear are important. Two sets of sagittal measures are crucial: the angle of the ankle in the AFO (AAAFO) and the position of the lower leg relative to a vertical to the ground when standing in the AFOFC, the Shank Angle to Floor (SAF). The selection of the basic design features of the AFOFC is highly critical to achieving orthotic goals. The AFOFC can be tuned by making fine adjustments to manipulate the Ground Reaction Force (GRF) and its relationship to knee and hip joints in order to optimise its performance (Meadows 1984, Butler and Nene 1991). One aspect of tuning is to set the SAF of the AFOFC. Alteration of the SAF by just a few degrees can influence the alignment of the GRF to the joints in standing and gait considerably (Cook & Cousins 1976, Meadows 1984). This paper reports the results of the tuned SAFs of solid AFOFCs for a population of children with cerebral palsy (CP), spina bifida (SB) and other conditions (O).

PATIENTS and METHOD
74 children (CP n=50, SB n=4, O n=20) who were independently ambulant without walking aids and who required solid AFOFCs had their prescriptions tuned at Bangor CDC on the ORLAU transportable Video Vector Generator Gait Laboratory. Children’s gait was analysed while walking barefoot, in footwear and in AFOFCs until they were tuned. The AAAFO, SAF and other prescription details were collected for each AFOFC trial.

RESULTS
Figure 1 shows the SAFs of the latest tuned prescriptions for each of the 74 children using 112 AFOFCs. Whether the AAAFO was dorsiflexed, plantigrade or plantarflexed the SAFs of the tuned AFOFCs were all inclined. For all AFOFCs (n=112) mean SAF=11.36°, SD=2.08, range 7-15°. For AFOFCs used by children with CP (n=69), mean SAF=11.86°, SD=2.05, range 7-15°. For AFOFCs used by children with SB (n=8), mean = 7.75°, SD=0.46, range 7-8°. AFOFCs for other children (n=35), mean =11.2°, SD=1.41, range 8-14°.

![SAF distribution by diagnosis](image)

Figure 1. Frequency distribution of Shank Angle to Floor of tuned AFOFCs by diagnosis

DISCUSSION
It is possible to measure in a simple manner the AAAFO and SAF. When tuning AFOFCs a good starting point would be to set the SAF at 10-12° inclined and increase or decrease the SAF as required, with the exception of AFOFCs for children with SB. The mean tuned SAFs approximate to the SAF of normal gait at midstance. A possible explanation for the 10-12° inclined SAF being central to the production of stability in stance in both normal and pathological gait with AFOFCs is that it is determined by anthropometric measures.10-12° inclined is the position that brings the centre of the knee joint directly over the middle of the foot. Other design features of the AFOFC need consideration if it is to be tuned optimally for the whole of the gait cycle.

REFERENCES
TUNING FOR THE ‘ENTRANCES TO MST’ AND ‘EXITS FROM MST’

**EXITS FROM MIDSTANCE**

- **TUNING PROCESS**
  Trials by slow motion kinematic video, with or without kinetics, to optimise kinematic / kinetic gait parameters

- **TUNE MIDSTANCE** by adjusting Heel Sole Differential of the AFOFC to determine the SHANK ANGLE TO FLOOR of the AFOFC which produces optimal shank kinematic and GRF alignment. A useful starting point for tuning is '10-12°' incline.

- **TUNE EXIT FROM MST (TST)** by adjusting sole design to optimise shank kinematic and GRF alignment

  - Flexible sole with flat or rounded sole profile produces optimal result?
    - **YES**
    - **SOLE DESIGN**
  - **NO**
    - **SOLE DESIGN**

- **USE OF ANATOMICAL 3rd ROCKER**
  - Stiff sole with rocker sole profile (optimised position and toe spring angle) produces optimal result?
    - **YES**
    - **SOLE DESIGN**
  - **NO**
    - **SOLE DESIGN**

- **USE OF SIMULATED 3rd ROCKER**
  - Stiff sole with point loading rocker (optimised position and toe spring angle) produces optimal result?
    - **YES**
    - **SOLE DESIGN**
  - **NO**
    - **SOLE DESIGN**

- **TUNE ENTRY TO MST (IC, LR)** by adjusting heel design to optimise shank kinematic and GRF alignment

  - Plain heel produces optimal result?
    - **YES**
    - **HEEL DESIGN**
  - **NO**
    - **HEEL DESIGN**

  - Angular velocity of shank during entry to MST needs to be reduced by use of a negative or cushion heel?
    - **YES**
    - **HEEL DESIGN**
  - **NO**
    - **HEEL DESIGN**

- **TUNE ENTRY TO MST (IC, LR)** by adjusting heel design to optimise shank kinematic and GRF alignment

  - Angular velocity of shank during entry to MST needs to be increased by use of a positive heel?
    - **YES**
    - **HEEL DESIGN**

**ENTRANCES TO MIDSTANCE**

A PROPOSED CLINICAL ALGORITHM FOR DORSIFLEXION FREE AFOFCs
BASED ON CALF MUSCLE LENGTH, STRENGTH, STIFFNESS AND SKELETAL ALIGNMENT

Owen E (2013) Presentation for ISPO UK MS Annual Scientific Meeting 2013

Is there sufficient gastrocnemius length to allow knee extension with 10° ankle dorsiflexion and a non compromised arch?  

YES  

Is there sufficiently low tone in the calf muscles to allow 10° of ankle dorsiflexion during second rocker of gait cycle?  

YES  

Is there sufficient calf muscle strength to prevent excessive ankle dorsiflexion in stance and create a ‘quasi-stiff’ ankle in dorsiflexion in 3rd rocker?  

YES  

Is the triplanar bony alignment of the foot sufficiently stable to be maintained during the dorsiflexion free function of the AFO?  

YES  

A dorsiflexion free AFOFC design is likely to be suitable. Determine plantarflexion function. MTPJs free design usually required* 0° pitch/0mm Heel Sole Differential footwear required for full effect on ankle dorsiflexion** Optimal heel design in footwear required  

NO  

Fixed ankle or dorsiflexion stop AFOFC design required  

* An AFOFC with MTPJ free design is usually required, to allow MTPJ extension during third rocker, and patients who meet the criteria for a dorsiflexion free AFO usually meet the criteria for an MTPJ free design. If they do not a rocker sole profile is required on the footwear as restriction in MTPJ extension may produce excessive ankle dorsiflexion, a compensatory response required to enable normal shank kinematics if MTPJs are fixed and not compensated for by a rocker sole profile.

** To obtain 10-12° of ankle joint dorsiflexion in gait the dorsiflexion free AFO needs to be combined with footwear that has a 0mm Heel Sole Differential (HSD) or 0 degree pitch. For each degree of pitch in the footwear there will be a reduction of one degree of ankle dorsiflexion. This is because gait requires normal shank kinematics and ankle joint kinematics adjust to the pitch of the footwear to achieve this. In normal gait the shank is 10-12° inclined at the end of mid-stance. A 10-12° pitch in the footwear negates the need for ankle dorsiflexion to achieve this.
When teaching first early steps, or first steps with a new design of AFOFC, to children with significant problems of muscle stiffness, muscle weakness, balance or other disabilities, it is useful to use the following sequence:

**A** Teach standing in AFOFCs which have optimised inclined SVAs of the AFOFCs. This is determined by standing trials (B). Choose the SVA that allows the child to obtain vertical or if possible inclined thighs, as it’s only when this is achieved that the GRF can pass anterior to the knee joint centre and produce stabilising moments at the knee. The AFO needs to be combined with footwear that provides a very stable base. This footwear would have a flat sole profile, with an appropriate rocker design, rounded or point-loading, at the appropriate percentage of the shoe/boot length, and may also include a back float. This design will provide a good base of support.

**B** In standing, encourage translation of the trunk anteriorly and posteriorly, moving the thigh from a reclined to vertical and inclined positions. Initially, they may need distal support at the top of the shanks to be able to do this.

**C** Encourage small steps with the stance leg moving from an MST position to an early TST position, with the thigh inclined and the GRF becoming aligned anterior to the knee and posterior to the hip, providing stability in stance.

Ref: Owen E, Course Manual
Implementation of AFO FC at the Rehabilitation Institute of Chicago – Donald McGovern, CPO, FAAOP

Some things we have learned since 2007

**USE THE ALGORITHMS**

- Get Physician/Therapist/Orthotist support
- Create a team based on temporal and geographic availability AND interest – we have an in house core staff of a Physician, two Orthotists, two Physical Therapists
- External staff through word of mouth, presentations
- Grow slowly, establish a loose protocol – clarify the protocols with experience – e.g. we initially did not stipulate GMFCS levels, received some inappropriate referrals, currently prefer GMFCS levels I, II, III
- Improve gait analysis skills using the four rocker “points of clarity.”
- Shoes are always a challenge – create a list as you gain knowledge
  - Flat bottom, laces that extend to the toe, removable insole
  - May need boys shoes for width, 1-2 sizes larger than customary
    - E.g. Keeping Pace, K-Swiss, Skater Shoes, basketball shoes, Answer2, Apisfootwear.com
    - The process is accelerated if client comes to the fitting with shoes that can accept the device, too many times the client returns with shoes that are too small.
  - We have not found a leather type boot to date – some at Apisfootwear.com look promising
  - Carbon Footplates can be added to shoes for rigid sole
  - Assess the shoe for flatness and soft/hardness of heel
  - Consider if shoes are an integral part of the device for insurance reimbursement

- A point concerning cosmesis, 30 years ago the vast majority of prosthetic users demanded cosmetic covers, now several prosthetic users proudly wear their devices unadorned, attitudes on cosmesis change.

**AFO FC is a Time Investment**

- Introducing AFO FC concepts to the family/client.
- Parents have an easier time understanding “balance the body over the foot” rather then placing the “Center of Mass over the Base of Support.”
- Have examples of a Tuned AFO, pictures at least.
- Use the just taken impression to demonstrate the amount of Shank to Vertical Inclination expected.
- Demonstrate that the raised foot trim lines that will be in the AFO will require large, deep shoes and a possible high top style.
- Create a brochure for caretakers appropriate for entire team
- An informational video would be helpful
- Location may dictate who does what, when.

The fitting of the orthoses requires additional time for the dynamic tuning process:
  - Must be done with at least one video camera
  - The file needs to be loaded onto a secure computer, which can slow down the video replay for gait assessment
  - Multiple alignment iterations require repeating the process
  - Requires dedicated space with some degree of privacy – public hallways impede process

**Who should be referred?**

- The client may be identified by the PT, Orthotist or Physician
- If by PT, the therapist can discuss the concept and make the arrangements with the Orthotist.
- If by Orthotist, the Orthotist must recommend the client to PT familiar with AFOFC and/or one willing to learn.
- Discuss with client and parent/caretaker. The client must realize that the time, the therapy, and the financial investment in the tuning process is above standard orthotic intervention alone.
- Educate the physician.
• Identify the patient - motivated, compliant client with supportive caregivers
• Dedicated AFO FC Physical Therapist is critical.
• Client functional level, start with GMFCS level I and II
  Start simple, e.g. young GMFCS, CP hemi with excessive knee hyperextension, no rotation issues, no stiff knee gait, etc.
• History of AFO usage for gait, especially of poor AFO seating
• Evaluation - “the Nines” – use the ALGORITHMs
  o Functional Soleus lengthening
  o Gastrocnemius shortening
  o Dundee angle adds clinical relevance
• Impaired Motor Control – external force to guide in a specific task, better tackled as you get experience.
• RIC currently has a monthly AFO-FC Clinic staffed by a Physician, two Physical Therapists and two Orthotists. We use two Casio Exilim Ex-FH20 cameras on tripods to record in the coronal and sagittal planes
• Off-site orthotists incorporate AFO-FC and use point and shoot camera video – 30 fps is adequate.
  o “Trying to analyze gait in pediatrics without the slow motion video is like trying to drive and text at the same time”

Orthotic Clinical Benefits
• Impression is easier to take
• Modification of the foot and ankle simpler
• Less time spent relieving pressure areas
• Improved lower extremity alignment
• But more time adjusting SVA at the fitting - IF shoes are available.
• More time tuning

The starting point for Tuning an AFO:
• Ankle Angle is determined in the Open Chain Evaluation.
• Bench Angle of the AFO is usually 8-10° of inclination depending on expected shoe wear
• Tuning begins with external or internal wedging with footwear to achieve the optimal SVA of the AFOFC in the Closed Kinetic Chain evaluation using video recording or a gait lab with vector analysis.
  ✓ Support child in standing
  ✓ Measure SVA (goal is usually 10-12°)
  ✓ Inclined shank with thighs vertical
  ✓ If the child is a stander already they may spontaneously rock forward and back since they now have anterior and posterior lever arms
  ✓ If contractures/spasticity/rotation issues, the client will likely need support since compensations have been removed
  ✓ If person is standing well, add some perturbations
  ✓ If person responds well to perturbations, initiate steps>gait
  ✓ Video record and assessment using the Four Rocker points of clarity and Algorithms
  ✓ Point Loading Rockers
  
  Wedge Sources: Alimed Achilles Boot Wedges (CBB66377)
  Adjust-a-Lift
  Crepe or Black Rigid Plastizote

Other Benefits
Our experience has been that we grow in confidence recommending the concept because ROM has not been lost and we have seen a decrease in the fitting issues with improved functional gait
  1. Naviculars are not calloused.
  2. Calcanei are not pumping – dustless heel AFOs.
  3. Tolerance for orthotic wear increases.
  4. Some ambulating patients (adult and children) report a decrease in fatigue and pain.
  5. Improved pelvic rotation with hip extension – especially noteworthy in very young persons with hemiplegia.
  6. Improved stride length gained, with long term users stride length gain carries over to non-AFO gait.
7. Observed improved heel toe gait – Example: One client’s physician parent remarked it was the first time the child had a heel toe gait since the child began walking.

Possible Therapeutic Benefits
- Role in motor learning
- Functional application to home program - Wii board excellent to improve proximal strength and balance, wonderful for parents to see a child who was unable to stand on the Wii board playing for 30 minutes wearing the AFO FC.
- Lengthening while ambulating – gastrocnemius, hamstrings, hip flexors
- Improve Gastrocnemius to Soleus ratio
- Increase demand on system, especially proximally
- Retrain hip strategy
- In new walkers does the stability in stance phase, especially the 3rd and 4th rocker prevent, reduce, or in any way have a positive influence on stiff knee gait?
- Role in prevention of atrophy, dysfunction, and pain

It seems....
- Best acceptance occurs when the client understands the concept AND gratification is immediate.
- Most immediate positive results with young, dystonic, equinus, knee hyperextension or weak soleus clients.
- Young adult clients with joint pain – process is very slow.
- Clientele under five years of age accept AFO FC.
- Those who must now start “learning how to walk again” tend to have difficulty accepting the change (10-20 year olds).
- It is advisable in some cases to emphasize AFO FC should be used as a gait training device, as opposed to all day AFO.
- Reassessment reimbursement is absent for Orthotists.

Challenges
- Therapists not familiar with AFO FC find it more difficult to accept.
- Clientele with multiple influences - two, three or four different therapy sites each with a different philosophy.
- Therapy focus is often altered with a tuned AFO since proximal issues become more obvious and are often more difficult to treat.
- Some functional walkers lose their compensations, which temporarily makes walking more difficult – increases parental concerns, decreases client’s confidence. Absolutely must be discussed with client prior to initiating the process.
- Encourage parents to record video of client before and after use to maintain a chronological visual record to note changes/improvements.
- The major concern to everyone who is unfamiliar with AFO FC is loss of ROM; as Algorithm recommends use other interventions to maintain/improve ROM if it is a concern.
- Weight of shoe wedge, lifts, Point Loading Rocker – especially with large Ankle Angle – modify wedge from crepe to hollow plastic.
- Cosmesis
- Time spent to don/doff was initially an issue, but all of the present adult clients are independent.
- User fluctuation in motivation – tuning will assist gait, but for the optimal benefits it will take perseverance, repetition and time.
- Is it reasonable to include shoes as an integral part of the Orthosis for billing?
- Reassessment takes at least one full session - time for clinician to review video in slow motion.

Currently working on two studies involving AFO-FCs:
1. “Improving Lower Extremity Orthotic Management of Children with Cerebral Palsy” funded by a Small Grant Award from the Orthotic and Prosthetic Education & Research Foundation (OPERF), Co-Principal Investigators: Stefania Fatone, PhD and Larissa Pavone, MD
2. “Pilot Study: Effect of Two Orthotic Approaches to Ankle Motion Restriction on Activity Level, Balance and Patient Satisfaction in Children with Cerebral Palsy” funded by Ultraflex Systems Inc., Principal Investigator: Deborah Gaebler-Spira, PhD
### CASE STUDY I - DIPLEGIA

#### KINEMATICS

**CASE STUDY DESCRIPTION**

- **Sex**: Male
- **Height**: 161.5 cm
- **Weight**: 90.5 kg
- **Age**: 12 yrs
- **GMFCS**: II

**Condition**

- walked at normal self-selected comfortable walking speed in two conditions: no AFO (unmodified shoes) and with bilateral AFO-FCs (modified shoes)

**Clinical Exam**

<table>
<thead>
<tr>
<th>PROM</th>
<th>R</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thomas Test</td>
<td>12</td>
<td>14</td>
</tr>
<tr>
<td>Knee Ext</td>
<td>180</td>
<td>180</td>
</tr>
<tr>
<td>DF (knee 90 deg)</td>
<td>84</td>
<td>85</td>
</tr>
<tr>
<td>DF (knee ext)</td>
<td>84</td>
<td>91</td>
</tr>
</tbody>
</table>

---

<table>
<thead>
<tr>
<th>% gait cycle</th>
<th>No AFO</th>
<th>AFO-FC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trunk Forward Tilt</td>
<td><img src="image1" alt="Graph" /></td>
<td><img src="image2" alt="Graph" /></td>
</tr>
<tr>
<td>Trunk Lat Bend</td>
<td><img src="image3" alt="Graph" /></td>
<td><img src="image4" alt="Graph" /></td>
</tr>
<tr>
<td>Trunk Rotation</td>
<td><img src="image5" alt="Graph" /></td>
<td><img src="image6" alt="Graph" /></td>
</tr>
<tr>
<td>Pelvic Tilt</td>
<td><img src="image7" alt="Graph" /></td>
<td><img src="image8" alt="Graph" /></td>
</tr>
<tr>
<td>Pelvic Obliquity</td>
<td><img src="image9" alt="Graph" /></td>
<td><img src="image10" alt="Graph" /></td>
</tr>
<tr>
<td>Pelvic Rotation</td>
<td><img src="image11" alt="Graph" /></td>
<td><img src="image12" alt="Graph" /></td>
</tr>
<tr>
<td>Hip Flex/Ext</td>
<td><img src="image13" alt="Graph" /></td>
<td><img src="image14" alt="Graph" /></td>
</tr>
<tr>
<td>Hip Abd/Add</td>
<td><img src="image15" alt="Graph" /></td>
<td><img src="image16" alt="Graph" /></td>
</tr>
<tr>
<td>Hip Ext Rot/Int Rot</td>
<td><img src="image17" alt="Graph" /></td>
<td><img src="image18" alt="Graph" /></td>
</tr>
<tr>
<td>Knee Flex/Ext</td>
<td><img src="image19" alt="Graph" /></td>
<td><img src="image20" alt="Graph" /></td>
</tr>
<tr>
<td>Knee Var/Val</td>
<td><img src="image21" alt="Graph" /></td>
<td><img src="image22" alt="Graph" /></td>
</tr>
<tr>
<td>Ankle DF/PF</td>
<td><img src="image23" alt="Graph" /></td>
<td><img src="image24" alt="Graph" /></td>
</tr>
<tr>
<td>Foot Orientation</td>
<td><img src="image25" alt="Graph" /></td>
<td><img src="image26" alt="Graph" /></td>
</tr>
</tbody>
</table>

---

**Notes:**

- The graphs above illustrate the kinematic data for the specified conditions.
- The data is presented in degrees for various joints during the gait cycle.

---

**References:**

- AACPDM 2013 INSTRUCTIONAL COURSE
- OWEN, GAEBLER-SPIRA, FATONE, MCGOVERN
CASE STUDY II - DIPLEGIA
KINEMATICS

CASE STUDY DESCRIPTION
Sex Male
Height 149 cm
Weight 38 kg
Age 12 yrs
GMFCS III

Condition walked at normal self-selected comfortable walking speed in two conditions: no AFO (unmodified shoes) and with bilateral AFO-FCs (modified shoes)

Clinical Exam
PROM
Thomas Test 13 14
Knee Ext 183 189
DF (knee 90 deg) 110 95
DF (knee ext) 92 85
CASE STUDY II - DIPLEGIA
KINETICS

<table>
<thead>
<tr>
<th>No AFO</th>
<th>AFO-FC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg</td>
<td>R</td>
</tr>
<tr>
<td>Step Width (cm)</td>
<td>12.0</td>
</tr>
<tr>
<td>Speed (cm/s)</td>
<td>118.3</td>
</tr>
<tr>
<td>Stride Length (cm)</td>
<td>130.2</td>
</tr>
<tr>
<td>Cadence (steps/min)</td>
<td>109.3</td>
</tr>
<tr>
<td>Step Length (cm)</td>
<td>65.2</td>
</tr>
<tr>
<td>Stance Time (%)</td>
<td>60.5</td>
</tr>
<tr>
<td>Swing Time (%)</td>
<td>39.5</td>
</tr>
<tr>
<td>Double Support (%)</td>
<td>10.2</td>
</tr>
</tbody>
</table>

Vertical GRF
M-L GRF
A-P GRF
Hip Flex/Ext Moments
Hip Abd/Add Moments
Hip Power
Knee Flex/Ext Moments
Knee Var/Val Moments
Knee Power
Ankle DF/PF Moments
Ankle Power