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CONTINUED

Hot Topics in Pediatrics

Guest Editor: Lisa Kenyon, PT, DPT, PhD, PCS

11/5: Evidence Based Physical Therapy Management of Idiopathic Toe Walking
Sally P. LeCras, PT, DPT, PCS

11/6: What Are We Waiting For? The Power of Early Mobility
Lisa Kenyon, PT, DPT, PhD, PCS

11/7: Meeting the Sensory Needs of Children with Autism Spectrum Disorder (ASD): A Primer for Therapy Professionals
Melissa Tovin, PT, MA, PhD, PCS, CEEAA

11/8: Keys to Physical Literacy and Fundamental Movement Skills for Children Who Use Wheelchairs: Consideration for Adapted Sport and Inclusive Physical Education
Krista Best, PhD

11/9: Clinical Application of the Congenital Muscular Torticollis Clinical Practice Guideline
Micah Huegel, PT, DPT

CONTINUED

Evidence Based Physical Therapy Management of Idiopathic Toe Walking

Sally Le Cras, PT, DPT, PCS

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CONTINUED

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Learning Outcomes

After this course, participants will be able to:

- Identify at least two of the current theories regarding the etiology of Idiopathic Toe Walking (ITW).
- Identify at least three items from patient history and examination that may warrant further medical workup for a child who toe walks.
- Describe at least three evidence-based components of a physical therapy examination to determine an appropriate plan of care for a child with ITW.
- Outline at least three evidence-based physical therapy interventions for ITW.
- Identify when to refer a child with ITW for medical interventions including Botox injections and surgical interventions.

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CONTINUED

What is Idiopathic Toe Walking?

- Diagnosis for children over the age of 2 years who ambulate with a bilateral toe-toe pattern without any known reason or pathology. *(Sala 1999, Fox 2006)*
- Starts within 6 to 12 months after onset of independent walking
- Diagnosis of exclusion

Incidence of ITW

- 5% of children in Sweden *(Engstrom 2012)*
- 12% of children in Netherlands *(Engelbert 2011)*

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Idiopathic Toe Walking

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When is toe walking NOT "idiopathic"?

If child has a medical or psychiatric diagnosis associated with toe walking, it is not considered Idiopathic Toe Walking.

Central Nervous System disorders

- Cerebral palsy
- Tethered cord
- Traumatic brain injury
- CVA/stroke
- Spina bifida
- Spinal tumor

Peripheral Nervous System disorders

- Charcot-Marie-Tooth disorder

Vascular disorders

- Vascular malformation of lower extremity

Genetic disorders

- McArdle's disease

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When is toe walking NOT "idiopathic"?

Neuromuscular disorders
- Spinal Muscular Atrophy
- Muscular Dystrophies

Trauma
- Injury to leg, ankle or foot resulting in toe walking

Orthopedic disorders
- Club foot
- Arthrogryposis

Neuropsychiatric disorders
- Autism
- Bipolar disorder
- Schizophrenia

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Etiology of ITW

Unknown cause, may vary and may be multimodal

Current Theories:
- Genetic
- Neurologic
- Sensory

Genetic Theory

Genetic Predisposition

- Family history of toe walking has been reported in 17 to 61% of ITW cases *(Engstrom 2012, Insuga 2018, Pomarino 2016, Martin-Casas 2017)*

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Sensory Theory

- Significant differences in scores on sensory processing measures between children with ITW and typically-developing children have been reported
- Published reports indicate that the type of sensory impairments are not universal in ITW, suggests heterogeneous population
- Children with ITW may be HYPERsensitive or HYPOsensitive to sensory input: tactile, vestibular, proprioceptive.

(Fanchiang 2014, Ganley 2016, Williams 2012, Williams 2013, Williams 2014)

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Neurologic Theory

- ITW assoc w/ greater incidence of complications during & after birth compared to children who do not toe walk. Complications include: prematurity, lower birth weight and admission to special care nursery *(Baber 2016)*
- ITW assoc w/ greater incidence of language delays. *(Arcardo 1992, Shulman 1997)*
- Motor and sensory impairments may indicate immaturity or mild impairments of motor cortex or cerebellum *(Williams 2014)*
- Children w/ ITW displayed more neuropsychiatric problems than group of age-matched typically developing children. *(Engstrom 2012)*

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Neurologic Theory

Children w/ ITW displayed more neuropsychiatric problems than group of age-matched typically developing children. *(Engstrom 2012)*

- Motor skills 39.0%
- Executive function 17.6%
- Perception 25.5%
- Memory 23.5%
- Language 23.5%
- Learning 25.9%
- Social skills 25.5%
- Emotional/behavioral problems 21.6%

20.8% of children with ADHD presented with TW *(Insuga 2018)*

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Incidence of Non-Idiopathic Toe Walking

(Haynes 2018)

- Purpose: to review neurology findings of children referred from orthopedics to neurology for toe walking (TW)
- 108/174 children had non-idiopathic TW
- Diagnosis in order of prevalence:
  cerebral palsy, peripheral neuropathy, autism spectrum disorder, hereditary spastic paraparesis, ADHD, genetic syndrome and spinal cord disorder

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CONTINUED

Differential Diagnosis

Diagnosis	Key Features/"Red Flags"
Cerebral Palsy	UMN signs (spasticity, clonus, dystonia, + Babinski) Asymmetrical or unilateral toe walking History of prematurity or birth complications
Peripheral Neuropathy ex: Charcot Marie Tooth (CMT)	LMN signs (muscle atrophy, cavus feet, absent DTRs, decreased sensation) Possible unilateral toe walking Family history of TW
Autism Spectrum Disorder	Rigid, stereotyped behaviors or play activities Limited eye contact or delayed language, social, play skills
Hereditary Spastic Paraparesis	UMN signs (spasticity, clonus, + Babinski) Family history of TW
Spinal Cord Disorder ex: tethered cord, spinal tumor, spinal cord infarct	UMN signs (spasticity, clonus, + Babinski) Possible unilateral toe walking Concerns regarding potty training or bowel/bladder control

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CONTINUED

Diagnosis	Key Features/"Red Flags"
Neuromuscular: Muscular Dystrophy or Spinal Muscular Atrophy	May have history of delayed ambulation Late-onset toe walking (3 to 5 years old) Calf hypertrophy Wide base of support, lumbar lordosis + Gower's sign History of progressive weakness or loss of motor skills
Orthopedic	Leg length difference Club foot (rigid, PF/inverted/adducted foot) Hip pathology Scoliosis Foot/ankle bony abnormality
Genetic: McArdle's Disease	Recurrent body pain with difficulty localizing specific area Atrophy of biceps/triceps and shoulder girdle Myoclonus of hands Gastrocnemius hypertrophy Wide forefoot with narrow heel "Second wind phenomenon" after 6-8 minutes of exercise

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Typical Gait Development

Two phase process of gait acquisition:

1. Learning gait posture requirements
   - 3 to 6 months after independent ambulation
2. Fine tuning of gait, lasts several years
   - Gait maturation dependent on central nervous system maturation and height/growth
   - By 7 years of age, adult muscle activation pattern is complete
   - By 8 years, head control, head/trunk control and anticipatory postural adjustments mature.

(Breniere 1998)

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Development of Heel Strike

Initial walking pattern:

- forward trunk lean/hip flexion, little ankle DF or PF, stepping by falling
- heel strike evident at 22 weeks (mean) after onset of independent ambulation or by 50 weeks post independent ambulation *(Sutherland 1980)*

Evidence that toe walking is a normal gait deviation in 1 to 3 year olds is lacking. *(vanKuijk 2014)*

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Mature Gait

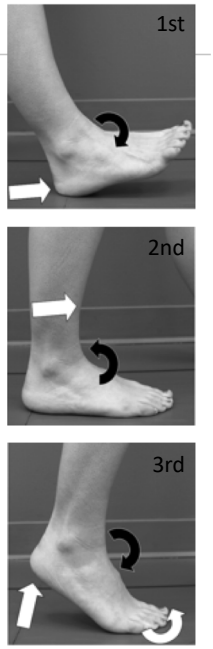
It's not just about the heel strike!

Phases of stance:

1st, 2nd and 3rd ankle rockers

- **1st rocker:** ankle plantarflexion after heel strike until foot flat
- **2nd rocker:** forward translation of the tibia over the foot
- **3rd rocker:** push of

(Davids 2007, Hicks 1988, Westberry 2008)



Images from Davids 2007. Used with permission.

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ICF Model

International Classification of Functioning, Disability & Heath, World Health Organization (WHO 2001)

- Medical Condition
- Body Function/Body Structure Impairments
- Activity Limitations
- Participation Restrictions
- Contextual Factors
  - Internal
  - External

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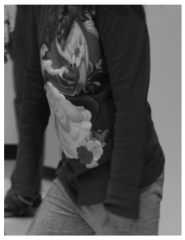
Body Structure & Body Function Standing Posture Impairments

Trunk/Hip/Pelvis

- **Equinus or Plantigrade**: lumbar lordosis, anterior pelvic tilt, hip flexion
- **Plantigrade:** possible hip external hip rotation



Knee

- **Plantigrade**: possible knee hyperextension

Foot/Ankle

- **Equinus:** ankle PF, calcaneovarus, calcaneovalgus or neutral hindfoot
- **Plantigrade:** forefoot abduction, calcaneovalgus and navicular drop (over pronation), or neutral ankle/foot

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Body Structure & Function PROM Impairments

Hip

- Hip flexors (limited hip extension)

Knee

- Knee flexors (limited hamstring flexibility)

Ankle

- Ankle plantarflexors (limited ankle DF - especially knee extended = gastrocnemius

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Activity Limitations – Equinus Gait

- Excessive PF in stance and swing phase
- Lack of 1st and 2nd rockers → lack of heel strike and decreased transfer of body weight over foot during stance
- Lack of 3rd rocker → poor push off
- Decreased/absent mid-stance knee flexion
- Increased anterior pelvic tilt
- May be able to walk with foot flat or heel-toe intermittently
- Short stride length

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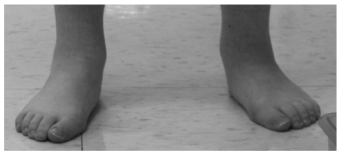
Activity Limitations - Plantigrade Gait

- Increased anterior pelvic tilt
- Excessive pronation in stance
- Decreased eccentric control during 1st rocker
- Inadequate/absent 2nd rocker
- Knee hyperextension during stance
- Decreased knee flexion in mid-stance
- Early heel rise
- Over recruitment of toe extensors in swing
- Short stride length



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Activity Limitations: Functional Mobility

May have difficulties with:

- Static standing/standing still
- Stand < > squatting
- Prolonged squatting
- Floor to stand transitions
- Immature stair skills
- Single limb stance
- Decreased ability to pedal bike/tricycle
- Tripping/falling

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Activity Limitations: Gross Motor Skills

- May demonstrate delayed balance skills and postural reactions
- Decreased fluidity, coordination, and rotational movements during activities such as running, skipping, galloping, and throwing/catching
- Decreased eccentric control and power generation during activities such as jumping and hopping

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Participation Restrictions

- Decreased safety while navigating home, school, and community environments
- May have difficulty keeping up with peers during functional mobility, gross motor play or sports/recreational activities
- May have decreased quality of life compared to peers without ITW

(Williams 2015)

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Natural History of ITW

Eastwood 2000
- 49 children in observation group
- At 2 -12 year follow-up, 50% parents reported improvement in gait.
- 12% with normal gait per physician report (same as casting group).

Engstrom 2012
- 1436 children in Sweden screened for history of toe walking at 5.5 years old
- 5% with history of TW, 50% of those children no longer TW per parent report
- Only 1/3 of "active" TW had significantly decreased ankle DF PROM
- Children with "resolved" TW were not examined

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Natural History of ITW

(Engstrom 2018)

Follow-up of 26/1401 healthy children who were still TW at 5.5 years old at ages 8 and 10 years

- 5/26 underwent Achilles tendon lengthening surgery
- 8/26 continued to TW walk at 10 years
- No significant difference in DF PROM KE from 5.5 to 10 years
- 4/26 had ankle plantarflexion contracture at age 10
- 10/26 had received a neurodevelopmental or other dx between 5.5 to 10 years

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Natural History of ITW

(Engstrom 2018)

Conclusions:

- 80% of children with ITW and no ankle contracture will cease TW by 10 years without treatment
- ITW does not result in decreased DF ROM over time
- 2 groups:
  - Ankle contracture birth - 5 years → "Need prompt treatment"
  - TW without contracture → "Treatment should be discouraged in this group"
- "no treatment has proven as effective as the natural history outlined in this study"

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Natural History
Inactive vs. Active Treatment

(Davies 2018)

- Long-term follow up (mean 13.4 years)
- Active (n = 23: combination of serial casting, Botox, and AFOs) vs. inactive treatment for ITW (n = 20: recommendations for stretching only)
- Outcome assessments included:
  - 3D gait analysis in MAL, ankle DF ROM, and activities/participation (Pediatric Outcomes Data Collection Instrumentation - PODCI or Short Form Survey - SF-36)

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Natural History
Inactive vs Active Treatment

(Davies 2018)

Results:

- Improvements in some gait variables in both groups from baseline to follow-up
- 91% still had atypical ankle movement patterns at follow-up
- Both groups had significantly limited ankle DF PROM at follow-up
- 17/43 participants reported mild or moderate - severity activity limitations at follow-up

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Why Treat Children with ITW?

Decreased ankle DF PROM associated with:

- Increased ankle injuries in children
- Increased forefoot, midfoot and/or hindfoot pain or pathology in adulthood
- Heel-toe gait with appropriate stance rockers requires 10 degrees of ankle DF with knee extended (in subtalar neutral).

(DiGiovanni 2002, Hill 1995, Tabrizi 2000)

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Why Treat Children with ITW?

Prevent or lessen long term impairments:

- acquired equinus *(Sobel 1997, Solan 2010, Williams 2013)*
- excessive midfoot pronation *(Solan 2010)*
- increased anterior pelvic tilt with hyperlordosis *(McMulkin 2006)*
- skeletal changes
  - increased external tibial torsion *(McMulkin 2006)*
  - abnormal bony development of foot: distal tibia, talus *(Sinclair 2017)*

Decrease impact on gross motor activities, participation in family, school, sports and community activities and overall quality of life. *(Williams 2015)*

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Referral to PT for ITW

- At present, cannot predict which children with ITW will cease toe walking without intervention.
- Based on neuromotor development and motor learning theories as well as data from body of evidence that longer time TW = increased ankle DF contractures - earlier intervention may lead to improved outcomes and decreased PT visits or episodes of care.
- Children with history of ITW may have impairments in PROM, strength, posture, gait and pain despite cessation of toe walking behavior.

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Indications for Physical Therapy

It is recommended that PT intervention be initiated for a child with ITW with these impairments/limitations:

- Limitations in ankle DF PROM
- Limitations in functional core or LE strength
- Pain
- Decreased balance
- Activity limitations, including gait impairments and gross motor delays, that impact ability to keep up with peers or quality of life

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Physical Therapy Examination for ITW

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Goals of PT Examination for ITW

1) Differential diagnosis: r/o non-idiopathic causes of TW. Refer to appropriate health care practitioner for further testing when does not appear to be ITW.
2) Determine need for PT intervention based on history, exam findings, and patient & family preferences/goals.
3) Provide patient/family with education about ITW and treatment options.
4) Collaborate with patient/family to determine optimal plan of care.

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History for ITW Examination

- Birth history
- Medical history
- Developmental history
- Toe walking history
  - Age of independent ambulation
  - Age of onset of toe walking
  - % of time toe walking
  - Has toe walking improved, gotten worse or stayed the same
  - Is toe walking better/worse/same on different surfaces (grass, carpet, tile)
  - Review past interventions for toe walking

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PT Examination for ITW

- Pain
  - location, timing, numerical rating score, what does pain prevent you from doing?
- Integument
  - feet, ankles
- Screenings
  - Speech and Language: Ages and Stages (ASQ 3)
  - Sensory Processing: Short Sensory Profile (SSP 2)
- Neurologic Exam (Modified Tardieu, DTR's)
- Musculoskeletal Exam
- Gait
- Gross Motor Skills
- Balance Skills

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Toe Walking Tool

Validated, reliable assessment tool to assist with differential diagnosis of toe walking

Does not diagnose ITW - assists with the decision of when to refer a child to a specialist for further work-up of toe walking

Four sections:

- Demographic information
- Indicators of traumatic cause for toe walking
- Indictors of neuromuscular cause for toe walking
- Indicators of neurogenic cause for toe walking

Mostly history taking, some exam items

(Williams 2010 & 2011)

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Toe Walking Tool

(Williams 2010 & 2011)

Question	Area	Answer
Name	Demographics	n/a
Date of birth	Demographics	n/a
Gender	Demographics	n/a
Does the child toe walk?	Demographics	n/a
Does the child have a condition that you have sought medical assistance for and/or been diagnosed with a condition causing TW ?	Demographics	n/a
Does the child have a family member who TW with no other medical condition?	Demographics	n/a
Walk on one foot only?	Traumatic	Yes
Toe walking in response to pain?	Traumatic	Yes

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Toe Walking Tool

(Williams 2010 & 2011)

Question	R/O Cause	Answer
Previously walk flat footed and only recently start to toe walk?	Traumatic or Neuromuscular	Yes
Able walk on their heels when asked to?	Traumatic or Neuromuscular	No
Have a diagnosis of autism?	Neurogenic	Yes
Have a diagnosis of CP?	Neuromuscular	Yes
Have a diagnosis of muscular dystrophy?	Neuromuscular	Yes
Family history of muscular dystrophy?	Neuromuscular	Yes
Birth weight over 2500 g? (5.5 pounds)	Neuromuscular	No
Over 37 weeks gestation at birth?	Neuromuscular	No
Admitted to special needs nursery/neonatal intensive care after birth?	Neuromuscular	Yes

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Toe Walking Tool

(Williams 2010 & 2011)

Question	R/O Cause	Response
Have more than 2 significantly delayed developmental milestones?	Neurogenic	Yes
Limited eye contact, strict rituals or ritual-related behaviors, that is, lining up toys, rocking or spinning?	Neurogenic	Yes
Positive Gower's sign?	Neuromuscular	Yes
Normal knee jerk reflex?	Neuromuscular	No
Normal Babinski?	Neuromuscular	No
a. Hip flexors tight for age? (Thomas Test)? b. Hamstrings tight for age? (Popliteal angle) c. Gastrocnemius and soleus tight for child's age? (Lunge Test)	Neuromuscular	If 2 of these are "Yes"

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Toe Walking Tool
Strengths & Limitations

Strengths:

- Valid and reliable tool (Kappa = 0.9028)
- Can be used by a variety of health care professionals

Limitations:

- Validity and reliability study had small number of child and clinician participants
- Tool is not diagnostic for ITW
- Unclear if "soft signs" warrant additional referrals or work-up (ie, spastic catch in gastrocnemius)

(Williams 2010 & 2011)

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Other Tests & Measures

Consider administration of standardized tests for gross motor development:

- Peabody Developmental Motor Scales (PDMS 2) *(Clark 2010)*
- Bruininks-Osertesky Test of Motor Proficiency (BOT II) *(Williams 2013)*
  - ITW group "below average" on Bilateral Coordination, Balance and Upper-Limb Coordination
  - By 8 years old, ITW group scored "average" on all but Upper-Limb Coordination

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Differential Diagnosis & Screenings

- If history or exam reveals neurologic, orthopedic, neuromuscular, psychiatric or other possible cause for toe walking, refer to appropriate medical practitioner for further work up.
- If child was a late walker (more than 15 months old) or started toe walking more than 12 months after independent walking, further medical work up of toe walking is indicated.
- If child only toe walks on one side, further medical work up of toe walking is indicated.

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PT Examination for ITW

Musculoskeletal Exam

- Sitting/standing postural assessment
- LE alignment tests: Thigh foot angle (TFA), Hindfoot and forefoot alignment in STN (non-weight bearing and weight bearing), Foot Posture Index (FPI-6)
- Muscle length tests: ankle DF PROM with knee flexed and extended (in STN), Thomas Test, Popliteal Angle
- Strength: anterior tibialis, gastrocnemius, quadriceps, hip extensors, trunk rotators and flexors

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Measurement of Ankle DF in STN

DF in STN

DF with ankle pronation

Allowing the ankle/foot to pronate during DF will result in inaccurately high DF PROM measure.

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Why measure ankle DF PROM in subtalar neutral?

- Pronation is a composite motion in 3 planes of motion and includes ankle dorsiflexion, foot abduction and calcaneal eversion.
- Allowing the ankle to pronate will give a falsely large ankle DF PROM measurement.
- Over-pronation in standing results in breakdown of the midtarsal joint in the foot over time, creates inefficient foot structure, may cause pain and can result in a rocker bottom foot deformity.

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PT Examination for ITW

Systems Review:

Pain Assessment
- Appropriate pain scale, location of pain, timing of pain

Integument
- Presence of calluses or redness
- Bruises on LE due to falls/tripping

Neurological Exam
- Muscle tone
- Deep tendon reflexes

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PT Examination for ITW

Strength:
- anterior tibialis
- gastrocnemius
- quadriceps
- hip extensors
- trunk rotators and flexors

Functional strength assessment during gross motor skill assessment is also important – esp. eccentric contraction of gastrocnemius and quadriceps

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PT Exam: PROM/Flexibility

Hip extension
- Thomas Test

Knee extension, hamstring flexibility
- Popliteal angle

Ankle dorsiflexion
- Measure in prone with knee flexed & extended, subtalar neutral (STN)
  - Typically, ankle DF KF is more than ankle DF KE
  - If ankle DF PROM is the same for both = may be Achilles tendon and/or joint capsule tightness, less likely to improve with conservative measures
- Lunge Test (functional ROM versus compensations)

(Williams 2013)

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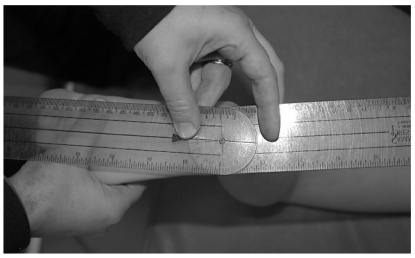
Thigh Foot Angle

Prone with the knee flexed to 90 degrees, ankle DF = 0° in STN. Bisect the plantar surface of the hindfoot. Measure the angle formed by the bisecting line of the thigh and the longitudinal axis of the hindfoot.

(+) = lateral deviation (ER)
(-) = medial deviation (IR)



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Hindfoot & Forefoot Alignment in STN
Non-weight bearing

Palpate medial and lateral heads of talus. Oscillate the foot (with 5th MT) between pronation and supination until both heads of the talus are felt equally.
This is subtalar neutral.

Alignment documented as varus, valgus or neutral hindfoot or forefoot.

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Plantigrade: Excessive Pronation

- Common finding in plantigrade standing in children with ITW.
- Compensation for tight ankle plantarflexors.
- Consists of: heel eversion (calcaneovalgus), forefoot abduction, ankle dorsiflexion.

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PT Examination: Strength

- Manual muscle testing
- Functional skills observations (ability and quality)
  - Core: prone extension, supine flexion, sit-ups
  - Walking: gait, walking on heels
  - Transitions: climbing onto toys/furniture, squatting, floor to/from stand
  - Gross motor skills: single limb stance, stair mobility running, jumping, hopping, tricycle/bicycle riding

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Idiopathic Toe Walking Severity

Two published scales

(Alvarez 2007)

Gait abnormalities in ITW

Mild (Type 1): typical gait pattern in plantigrade, hx of TW

Moderate (Type 2): abnormal or missing 1st & 3rd ankle rocker, predominant anke PF moment in late stance

Severe (Type 3): no 1st rocker, early transition to ankle PF, very increased ankle PF moment in early stance

Requires Motion Analysis Lab

(Beilmann 2016)

Frequency of toe walking

Grade 1: 76 to 100%

Grade 2: 51 to 75%

Grade 3: 26 to 50%

Grade 4: 10 to 25%

Grade 5: <10 %, early heel rise

Grade 6: normal heel strike

Does not account for ankle PROM or gait abnormalities

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Gait Examination: Parent Report

Parent report % time Toe-Walking

- *Strengths:*
  - Parent observation may be more reflective of gait in natural settings than observations in clinic
  - May reflect parent satisfaction with therapy
- *Limitations:*
  - Validity and reliability are not established

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Gait Examination: Clinician Report

- Child with ITW may change gait pattern when aware they are being observed – try to observe when child is not aware or distracted. *(Clark 2010)*
- Recommend observing barefoot AND with shoes/foot orthoses, if appropriate.
- 50-Foot Walking Test for ITW: valid and reliable measure for objectively measuring % time toe walking in children (measured in clinic) between the ages of 6-13 years in a clinical setting.
  (Christensen 2017)

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Observational Gait Assessments

- Edinburgh Visual Gait Analysis (EVAS)
- Observation Gait Analysis (OGA)
- Physician Rating Scale (PRS)
- **Observational Gait Scale (OGS)**
- Visual Gait Assessment Scale (VGAS)
- Salford Gait Tool (SGT)

(Bella 2012, Rathinam 2014, Moissenet 2015)

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Observational Gait Scale

- Modification of Physician Rating Scale
- Low tech tool to grade quality of ambulation
- Child walks 20 to 30 feet, observe in frontal and sagittal planes x 2, score LE independently.
- Areas Tested: knee position in midstance, initial foot contact, foot contact at midstance, timing of heel rise, hindfoot at midstance, base of support, assistive devices and change in gait.
- Does not assess hip or trunk. Primarily assesses stance phase variables.
- Each area is assigned a value between -1 to 3 and results are added up to a total score for R and L LE.
- Maximum (perfect) score is 22 per limb.

(Boyd 1999)

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Observational Gait Scale

- Reliability and Validity were established on a population of children with cerebral palsy.
- Intrarater reliability was 0.53-0.91 for areas 1-4 (most consistent: timing of heel rise) and 0.3-0.57 for areas 5-6.
- Interrater reliability was 0.43-0.86 for areas 1-5 (most consistent: knee position in mid-stance) and 0.29-0.45 in area 6.
- Validity was 0.54-0.94 in areas 1 4 of the OGS (compared to 3D digital gait analysis).

(Mackey 2003)

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Gait Examination
Observational Gait Assessments

- *Strengths:*
  - Readily available in clinics
  - Reliability may be enhanced when videotaped
- *Limitations:*
  - No specific tool validated for children with ITW
  - Significant variability noted in validity and reliability studies
  - Limited psychometrics on MCID and MDD
  - Unclear correlations with ROM, gross motor skills, posture, patient/family satisfaction

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PT Examination: Gross Motor Skills

Functional Mobility:
- Squat to stand transitions
- Squatting (maintain)
- Floor to stand transitions
- Stairs

Balance:
- Static and dynamic standing balance
- Single limb stance
- Balance beam
- Tandem walking
- Heel walking

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PT Examination: Gross Motor Skills

- Jumping
- Hopping
- Running
- Pedaling trike/bike
- Skipping
- Stair skills
- Galloping
- Jumping jacks
- Ball skills

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PT Eval for ITW: Bottom Line

To improve success of PT Interventions for a child with ITW, the PT Evaluation for child with TW should include:

- Thorough birth, medical, developmental and toe walking history
- Appropriate screenings for medical conditions that cause toe walking in children
- Appropriate screenings for co-morbidities of ITW
- Objective measures of Body Structure/Function Impairments, Activity Limitations and Participation/Quality of Life Restrictions
- Discussion of family/child preferences and values with regards to interventions and discussion of goals for PT episode of care

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Physical Therapy Interventions for ITW

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Conservative Management of ITW

- Stretching
- Strengthening
- Joint mobilizations
- Balance training
- Locomotor training
- Motor control intervention
- Taping
- Shoe modifications
- Orthotic interventions
- Serial casting
- Sensory-based interventions
  - Augmented auditory feedback
  - Whole body vibration
  - Visual feedback

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PT Intervention Priorities for ITW

Obtain at least 10 degrees ankle PROM DF with knee extended (stretching, night splints, serial casting)

⇩

Strengthening core and lower extremities, postural training, gross motor acquisition, locomotor training, balance training, sensory based interventions, orthotic management

⇩

Orthotic management & transition to HEP

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PT Intervention: Stretching Ankle PF

Evidence Summary -

- No study specifically addresses type or frequency of gastrocnemius or soleus stretching to maintain or improve muscle length in children with ITW.
- Stretching was part treatment plan in some studies.
- If child has less than 10 degrees of ankle DF PROM with knee extended, consider prolonged low - load stretch to increase muscle length, such as night splinting or serial casting.
- More ankle DF PROM with KE and KF is needed for stair and squatting skills

(Engstrom 2013, Bishop 2016)

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Stretching: Gastrocnemius





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Night Splinting

- Night time stretching splint
- Recommended for patient with 0 to 10 degrees ankle DF
- Goal is at least 10 degrees ankle DF with KE
- Add knee immobilizer (KI) if not gaining PROM, alternate KI (one leg per night)

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PT Intervention: Stretching

Beyond the ankle plantarflexors:

- Hip Flexors
- Knee Flexors

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PT Intervention: Strengthening

Evidence Summary -

- No study addresses efficacy of specific strengthening protocols for children with ITW.
- Anterior tibialis strengthening in several studies:
  - Heel walking (50 steps per day)
  - Active ankle DF
  - Walking up incline on treadmill
- Address functionally weak muscle groups
- Strengthening may include: closed-chain or open-chain exercises, eccentric versus concentric contractions, taping, biofeedback
- Focus on proper form and alignment

(Engstrom 2010, Jacks 2004, Williams 2014)

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Strengthening: Core

Core strengthening ideas:

- Superman reaches
- Supine soccer
- Dead bug
- Planks
- Sit-ups, sit ups with rotations
- Yoga poses

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Strengthening: Lower Extremity




Bridging
Half kneel to standing
Squatting

- Spiderman wall squats
- Wall slides
- Reaching under legs to retrieve toys
- Sit < > standing
- Prolonged squatting


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Strengthening: Ankle DF

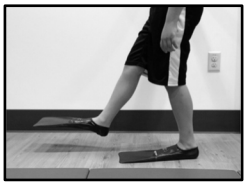
Open chain, concentric and eccentric

Resisted ankle DF

Picking up rings with foot

Standing Toe Raises

Heel Walking



Walking in flippers

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Strengthening: Ankle PF

Closed chain, eccentric & concentric

Incline

Calf raises

Moon shoes

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Locomotor Training

- Visual cues to increase step length with over ground training
- Treadmill
  - Walk forward on elevated treadmill
  - Backwards walking on treadmill (with or without elevation)
  - Increase speed to increase step length
  - Vary speed of treadmill to train power of ankle PF for push off

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PT Interventions: Balance Training

- Single leg balance with emphasis on soft knees, good LE alignment
- Modified single leg balance with one foot on ball or foam cube
- Balance beam – emphasis on heel-toe walking
- Tandem stance on balance beam with static or dynamic standing activities
- Sideways standing on balance beam during static or dynamic standing activities
- 2 or 3 wheeled scooter riding

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Single Limb Stance:
Marble Pick Up/Drop in Basket

Works foot intrinsics,
ankle DF and hip stabilizers -
also core if in good alignment.

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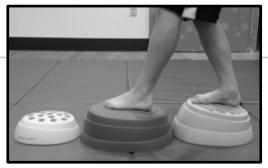
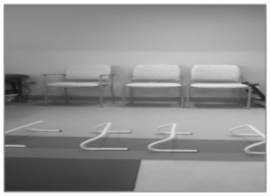
Motor Control



Children with ITW demonstrate gross motor immaturity, especially with activities that require weight shifts in stance or static standing.
These also provide functional strengthening.
Activities:

- Step ups/step overs
- Balance Beam
- Posterior weight shifts



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PT Interventions: Motor Control

(Clark 2010)

Case series n = 5 children with ITW, 2.5 - 6 years
Motor control intervention: 2x/week x 9 weeks + HEP
Main findings

- Resulted in improved ankle DF PROM
- Improvements on PDMS 2
- No sig improvements in spontaneous heel-toe gait

Additional treatment modalities for this population suggested:

- Measures to reduce sensory reactivity
- Serial casting to address initial DF limitations
- Orthotics for intrinsic foot instability

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Yoga and ITW

No evidence on YOGA & ITW

Potential benefits:

- Core, UE & LE strengthening
- Flexibility
- Motor planning
- Coordination
- Body Awareness

Downward facing dog, bridge, peacock, frog, table & windmill

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PT Intervention: Sensory Based

Whole Body Vibration (WBV)

- Theory: Children with ITW have altered vibration sensitivity in feet compared with controls *(Williams 2016, Ganley 2016)*
- WBV has been used to improve postural sway, and ambulation in adults with neurological impairment
- Literature:
  - WBV at 30Hz x 60 seconds, did not change gait kinematics in children with or without TW *(Fanchiang 2015)*

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PT Intervention: Sensory Based
Augmented Auditory Feedback

- One small low level study *(Conrad 1980)*
- Children wore auditory feedback heel switch x 1 hour per day
- May be useful when patient has full PROM, but needs reminders to practice heel-toe gait pattern.
- Examples:
  - Wee Squeaks http://www.weesqueak.com/
  - Ikiki shoes https://ikiki.co/collections/shoes/
  - Biofeedback/heel switch
- Consider using in a young child with ITW who has not developed muscle tightness

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PT Intervention: Sensory Based
Visual Feedback During Gait

- Case study, adult with ITW
- Treadmill, variable speeds while real-time footprints projected onto screen in front
- 30 minutes x 10 sessions over 3 weeks

Results:

- Increased heel contact time
- Decreased forefoot contact time
- Improved average pressure distribution
- Improved dynamic COP in AP direction
- Small improvement in ankle DF

(Pelykh 2014)

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PT Intervention: Sensory Based

Sensory Play:
pancakes with heels
in playdoh

Proprioceptive Input:
"Heavy-Work" Activities

(Clark 2010)
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PT Interventions for ITW: Bottom Line

Stretching, Strengthening, Locomotor Training, Postural Control Training, Balance Training, Motor Control & Sensory Based

- Research on specific PT interventions for ITW is limited
- Body function/body structure impairments, activity limitations, and participation restrictions observed in children with ITW indicate a need for PT for this population
- Interventions that address impairments and maximize function to allow pain-free participation in age-appropriate home, school, and community activities is warranted

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Orthotic Intervention

- Consider orthotic intervention when patient demonstrates toe walking > 25% of the time and/or demonstrates abnormal foot/ankle alignment during static/dynamic weight bearing.
- Should be considered to maximize range of motion gains and quality of gait following serial casting or surgical intervention.

(Herrin 2015, Stricker 1998)

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Orthotic Management

Orthotic styles used clinically for children with ITW:

- Ankle Foot Orthotics (AFOs, articulated with PF stop)
- Supramalleolar Orthotics (SMOs)
- Foot Orthotics (FOs)
- Carbon Fiber Foot Orthotics (CFOs)

Considered:

- Goal of orthotic
- Age of child
- Foot/ankle/LE joint mobility/ROM
- Cost/insurance
- Family preference and goals
- Presence of sensory or other impairments

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Orthotic Intervention: Articulated AFO

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Wedged DAFO # 2.0

- Allow ankle DF, blocks ankle PF
- Part of treatment plan for ITW (Davies 2018, Jacks 2004, Sala 1999, Tidwell 1999)
- May promote neuro-muscular re-education of heel-toe gait
- No studies look at isolated use of articulated AFOs
- One study comparing articulated AFOS to FOs

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Orthotic Intervention Supramalleolar Orthoses (SMO)

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Sure Step Toe Walking SMO

- Free ankle DF and PF
- Blocks inversion & eversion
- No published evidence
- Indications:
  - Child with excessive pronation
  - Consider SMO with posterior strut for sensory cue to decrease TW

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Orthotic Intervention: Foot Orthoses CO or CFO

- Case studies reported in the literature *(Williams 2014)*
- To improve foot/ankle stability and prevent recurrence of calf muscle contracture *(Beilman 2016, Williams 2014)*
- Consider adding carbon fiber to increase stability and proprioceptive input
- Assess need for HF or FF varus posting

Pattibob

Hotdog with carbon fiber

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Orthotic Intervention AFO vs CFO

- RCT: articulated AFO vs. CFO on gait
- ITW for 2-8 y/o, orthotics x 6 wks
- Results:
  - No significant differences in gait changes or effectiveness of AFO vs CFO
  - Parents reported CFO significantly easier to don
  - AFO group improved heel contact during stance compared to baseline with AFOs donned, unable to maintain in shoes-only
  - CFO group improved heel contact during stance compared to baseline with CFOs donned, able to maintain in shoes-only *(Herrin & Geil 2015)*

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Orthotic Interventions: Bottom Line

- Additional research is needed regarding most appropriate orthotic intervention for children with ITW
- Orthotic choice depends on many factors, children may need different orthotic at different stages of PT intervention.
- Clinical judgement, determining child/family goals and use of appropriate outcome measure are important

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Intervention: Serial Casting

Use of bilateral below-knee casts to provide prolonged, low-load stretch, with goal of improving muscle length and ankle PROM

- Typically 4 - 6 weeks, reapplication weekly
- Reassess PROM gains and skin integrity each week
- Outcome measures:
  - Ankle PROM KF and KE
  - Observational Gait Scale
- Well tolerated

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Serial Casting: Evidence Summary

- Improvements in ankle DF PROM noted in most studies *(Brouwer 2000, Fox 2006, Griffin 1977, Engstrom 2013)*
- EMG of anterior tibialis right after casting removal closely resembled typical gait pattern *(Griffin 1997)*
- Improved gait kinetics, including ankle power generation and ankle power absorption, observed after casting *(Engstrom 2013)*
- Serial casting in children with ITW resulted in increased DF PROM gains compared to children with CP and children with ITW maintained gains for a longer period of time *(Brouwer 2000)*

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Serial Casting: Bottom Line

- Serial casting is recommended for children presenting with ≤ 0 degrees of ankle DF KE
- May be used to increase if stretching or night splinting are unsuccessful
- Orthotic intervention recommended after serial casting
  - To maintain ankle ROM
  - To produce heel toe gait pattern
  - To optimize foot/ankle alignment during static and dynamic weight bearing activities
- PT episode of care is recommended to address proximal LE ROM restrictions, muscle weakness, activity limitations and participation restrictions.

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Medical Intervention: Botox

- Botulinum toxin type A = Botox
- Different manufacturers: Botox, Dysport, Xeomin
- Mechanism of action, local to site of injection: blocks release of acetylcholine → temporary paralysis of muscle
- Maximum response occurs at 2 weeks post
- Response dissipates by 3 - 6 months
- Has been used for children with ITW

(Beilman 2016, Engstrom 2010, Engstrom 2013, Jacks 2004, Kelly 2008)

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Medical Intervention: Botox Injections

Mixed results for use in ITW

- Botox improved gait kinematics and decreased toe walking in some children when used with HEP *(Engstrom 2010)*
- Children treated with Botox improved TW faster than children treated without Botox *(Beilman 2016)*

- Potential for adverse reactions *(Beilman 2016)*
  - 38 adverse effects in 30 treatments
  - 87% mild to moderate
- Botox + serial casting did not demonstrate significant differences in ankle DF PROM, ankle DF strength, gait variables or cessation of TW versus serial casting alone in an RCT *(Engstrom 2013)*

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Medical Intervention: Bottom Line

- Recommend serial casting without Botox injections for children with ITW
- Consider referral for Botox injections if sufficient PROM gains not made with casting alone or if toe walking does not resolve with conservative management
- Parents should be informed about the potential for mild to moderate side effects from Botox treatment

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Medical Intervention: Surgery

- Common procedures:
  - Open vs percutaneous procedures
  - Tendon lengthening, muscle lengthening or muscle resection (gastroc or gastroc + soleus)

Benefits:

- Sig improvements in key kinematic and kinetic gait variables 1 year post-op, maintained at 5 years post-op. Subjects reported satisfaction with outcomes, unrestricted activities and minimal pain at f/u. *(Hemo 2006, McMulkin 2016)*
- Improved ankle DF ROM *(van Kuijk 2014)*
- Peak muscle-tendon lengths increased in 83-86% of limbs after surgery *(Jahn 2009)*

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Medical Intervention: Surgery

Benefits: Parental satisfaction

(Eastwood 2000)

- 136 patients: observation, 6 wks casting, or triceps surae lengthening (surgery)
- Pt and MD-determined outcomes superior with surgery
- 72% surgical patients reported normal or improved gait vs. 51% in other 2 groups

(Stricker 1998)

- 80 patients treated with observation, casting, or surgery
- Improvement in DF 100% patients with surgery vs. 17% observation, 24 % casting
- 67% of parents satisfaction w/ surgery vs. 25% for casting or observation groups

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Medical Intervention: Surgery

Risks/Limitations

- Loss of push-off power in stance 1 yr post op *(Hemo 2006)*
- Postural deviations persisted: increased anterior pelvic tilt, decreased ankle DF in stance and increased external progression angle. *(McMulkin 2006)*
- Most patients had ankle DF in stance 2 SD less than age-matched controls post surgery (Stott 2004)
- Complications reported in 8/185 subjects, including achilles tendinitis, wound infection, and ankle fracture *(van Bemmel 2014)*
- Risk of over lengthening of muscle/tendon and infection
- Post operative protocols vary
- Toe walking can recur after surgical intervention

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Surgical Considerations

- Prior to surgical intervention, children with ITW with ankle PF contractures should have episode of PT including serial casting and/or night splinting
- Refer to Orthopedics for children with less than 10 degrees of ankle DF PROM KE despite conservative treatment, including serial casting and/or night splinting
- Refer to Orthopedics with hard end feel to ankle DF PROM with contracture or suspected bony anomaly
- Physical Therapy for locomotor training, strengthening, postural retraining, scar management and orthotic management should occur after surgery

(van Bemmel 2014)

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Discharge from Physical Therapy

It is recommended that a child be discharged from PT when the following expected outcomes have been achieved:

- Ankle DF PROM with knee extended ≥ 10 degrees
- Toe walking < 25% of the time per clinician or parent report
- Independence with HEP
- Age-appropriate balance and gross motor skills

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Follow-Up by Physical Therapist

It is recommended that parents/caregivers be instructed that plateaus or regression in ankle ROM and/or return of toe walking may occur due to:

- Growth spurt
- Anxiety
- Fatigue/illness
- Decreased compliance with home program

Children with ITW may require multiple episodes of PT intervention throughout their childhood to maximize outcomes.

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Case Study

9 y/o old male

First cousin has ITW.

Orthotics previously – did not tolerate wearing them – night stretching AFOs

Pt c/o tripping and falling more often when wet, and tired of kids asking why he walked on his toes.

Pain with stretching: 3/10

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Case Study

Question	Response
Birth History	full term, no complications
Family History of TW	parent, grandparent, cousin
Other Dx	none
Activities that improve TW	tumbling, football
Activities that make TW worse	am, when getting out of bed
History of anxiety	no
Bowel/bladder changes	no
Previous treatment	PT gave HEP with stretching ex, parents not performing
Orthotic	night time stretching AFO, unable to wear due to pain
Developmental History	no Speech/Language Delay diagnosed, all developmental milestones met on time

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Case Study

Question	Response
Walking	walking independent at 9 months, TW noted at 2 years, worsening, no difference in TW when child is aware they are being observed versus unaware
Falling/Tripping	yes, occasionally
Sports/Activities	football, tumbling 1x/week, orchestra
Sensory Processing Screen	no dysfunction indicated on the Sensory Integration, Praxis, and Regulatory Referring Problems List.

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Examination

Range of Motion

Trunk: WFL

Joint Motion	Right	Left
Knee Flexion	WNL	WNL
Ankle DF KE	- 22 degrees	- 23 degrees
Ankle DF KF	- 32 degrees	- 32 degrees
Ankle PF	WNL	WNL

Flexibility

Popliteal angle Right: 115 degrees, Left: 110 degrees

Thomas Test (hip flexor): (+) right, (+) left

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Examination

Joint Motion	Right	Left
Trunk	difficulty supine to sit	
Hip Extension	3/5	3/5
Hip Flexion	3+/5	3+/5
Hip Adduction	4+/5	4+5
Hip Abduction	4+/5	4+/5
Knee Flexion	5/5	5/5
Knee Extension	3+/5	3+/5
Ankle DF	2/5	2/5
Ankle PF	5/5	5/5

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Examination

Functional Strength	Coordination
Stand to/from squat: on toes Hopping: on toes, poor push off Floor to standing: falling back to hands to sit, up through his left leg to stand. Balance: Single limb stance: right and left x 2 seconds Stairs: ascent and descent on toes, reciprocal, no handrails	Jumping jacks: Unable, can jump out and in w/o hands, w/ hands only jumps out. Same side scissor jumps: Unable. Opposite side scissor side jumps: Unable Same side tapping fingers/foot: Yes Opposite side tapping fingers: Unable, can't coordinate hand and foot

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Examination: Gait

Observational Gait Scale
- Right: 7/22
- Left: 7/22

Endurance: No concerns

Running
- Arm Swing: minimal
- Trunk Rotation: minimal
- On toes t/o cycle

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Serial Casting Progression

Week 0

Ankle DF KE
R - 32 degrees
L - 32 degrees
Ankle DF KF
R - 23 degrees
L - 22 degrees

Week 2

Ankle DF KE
R - 12 degrees
L - 10 degrees
Ankle DF KF
R - 8 degrees
L - 8 degrees

Week 3

Ankle DF KE
R - 4 degrees
L - 5 degrees
Ankle DF KF
R - 2 degrees
L - 4 degrees

Week 5

Ankle DF KE
R + 8 degrees
L + 10 degrees
Ankle DF KF
R +10 degrees
L + 12 degrees

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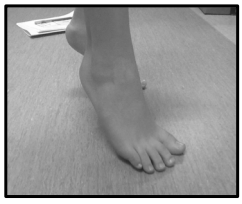

Progression of ankle/foot posture during serial casting episode of care: sagittal plane

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Progression of ankle/foot posture during serial casting episode of care: frontal plane

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Before serial casting

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Mid-serial casting

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After serial casting

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Two weeks post serial casting

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Before serial casting

After serial casting

Two weeks post serial casting

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Before serial casting

After serial casting

Six weeks post Tx

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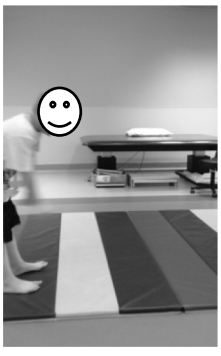
Before serial casting

After serial casting



Six weeks post Tx

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CONTINUED

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