A TOE WALKING WITH CLINICAL INTERPRETATION AND MANAGEMENT – AN OVERVIEW

Abstract

While frequent in young children, toe walking can develop into a persistent Problem with uncertain long-term effects. This thorough analysis dives into the complexity of toe walking in children, emphasizing the mysterious nature of "idiopathic toe walking" (ITW) or "habitual toe walking" (HTW) with no known explanation. While neurological conditions like cerebral palsy or muscular dystrophy can cause toe walking, ITW poses a distinct problem because it typically manifests in otherwise healthy youngsters. This chapter looks at the traits, categories, and methods of diagnosis for ITW, emphasizing the value of gait analysis and setting it apart from other developmental and neuromuscular disorders. It investigates several reasons, such as genetics and deformities of the muscles. ITW's administration is still debatable. The review compares surgical techniques like Achilles tendon lengthening with non-operative therapies including physical therapy, bracing, and casts, critically analyzing their efficacy. It highlights that age-appropriate treatment plans and early intervention are critical for the best results. It acknowledges the ongoing discussion regarding the necessity of interventions and goes over several treatment approaches, such as gait re-education and shoe adjustments. To sum up, this review provides a thorough and informative investigation of toe walking in children, especially the mysterious ITW. It gives parents and medical professionals important information to help them negotiate the challenges of diagnosis and treatment, ultimately leading to the best possible results for kids With this illness.

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I. INTRODUCTION

Toe walking is a natural stage in a child's gait development. However, a toe-to-toe walking pattern in a 2-year-old is considered atypical. Chronic toe walking can stem from various causes, including conditions like Duchene muscular dystrophy, cerebral palsy, congenital Achilles tendon contracture, and toe walking of unknown cause. Additionally, other factors like developmental issues, autism, spinal tumours, myopathy or neuropathic disorders might also contribute to toe walking. The long-term progression of toe walking of unknown cause remains uncertain. Prolonged untreated toe walking can heighten the risk of falls, limit ankle mobility, and lead to structural problems such as persistent outward tibia torsion. Nevertheless, research suggests that minor heel cord contractures can develop as frequently as slight regression when no treatment is administered. Long-term toe walking isn't associated with significant functional disruption, foot deformities, or pain.

A separate study indicates a connection between toe walking of unknown cause and learning difficulties, suggesting it as a potential indicator of developmental concerns. Diagnosis of toe walking of unknown cause is primarily through a process of elimination. Children displaying normal neurological examinations and birth histories might still develop toe walking of unknown cause. While the exact cause of toe walking of unknown cause is unclear, some experts hypothesize that a congenitally shortened Achilles tendon could contribute. Notably, around 30% of children with toe walking of unknown cause had a positive family history, hinting at possible involvement of autosomal dominance and variable expression. The diagnosis of toe walking of unknown cause generally relies on medical history and physical examination, although distinguishing it from mild forms of cerebral palsy, such as mild spastic diplegia, can sometimes be challenging.

II. CHARACTERISTIC FEATURES OF TOE WALKING

Toe walking, a common gait variation, is primarily associated with spastic paralysis, which is a prevalent cause. Individuals with conditions such as cerebral palsy (CP), traumatic brain injury, stroke, and those diagnosed with toe walking of unknown cause typically initiate their stance without making heel contact with the ground. This toe-to-toe walking style often results from factors like plantar flexor spasticity, contractures, and prolonged electromyography ankle plantar flexor activity. The reduced contact area with the ground due to toe walking leads to decreased stance stability, resulting in diminished velocity and shorter strides.

Recent findings propose that toe walking might offer compensation advantages, particularly for individuals with upper motoneuron lesions. Kerrigan et al. conducted a study involving physically fit subjects to analyse ankle and knee internal moments during toe and conventional heel-toe walking. Their research suggests that toe walking could potentially require less muscle strength in ankle plantar flexors, ankle dorsiflexors, and knee extensors than conventional walking, potentially offering compensatory benefits.

In a comparison of muscle activity during heel-toe and toe walking, Rose et al. utilized surface EMG. The study revealed premature gastrocnemius activity during previous swing and early stance while toe walking, along with longer tibialis anterior and quadriceps activity during terminal stance compared to mid stance. These findings indicate modifications

in calf muscle demand and effort exerted by knee extensors and ankle dorsiflexors during toe walking.

Muscle force output is influenced by the degree of overlap between actin and myosin filaments within the sarcomere, as noted by Gordon et al. Muscle fibres have an optimal length for maximal force production, and inadequate filament alignment within the sarcomere impairs force production, particularly in shortened positions. Joint position also affects passive contributions of muscles, ligaments, and soft tissues to internal moments, with increasing ankle dorsiflexion resulting in a growing passive plantar-flexor moment.

The significance of variations in electromyography activity and mechanical moments as joint positions change during walking is crucial. Recognizing that treatment attempts to alleviate equines may not be as essential as previously thought due to cost considerations can significantly impact patient care. Toe walking is linked to conditions like cerebral palsy, muscular dystrophy, autistic spectrum disorders (ASD), and global developmental delay (GDD). Additionally, unilateral toe walking, often associated with trauma-related events, such as injuries or tumours, can lead to physical inability to place the heel on the ground.

III. HABITUAL TOE WALKING / IDIOSYNCRATIC OR TOE WALKING OF UNKNOWN CAUSE

Toe walking of unknown cause also referred to as habitual toe walking, is characterized as an anomalous tiptoe gait pattern lacking neurological or orthopaedic causes. It entails the prolonged persistence of primarily physiological toe walking beyond the age of two. Instead of the heel, weight bearing occurs on the front of the foot during the initial contact of the gait cycle. Approximately 30% to 42% of habitual toe walkers exhibit a positive family tendency; nonetheless, for about 60% of these children, the exact cause remains unclear.

Children with habitual toe walking consistently prefer walking on the balls of their feet. This phenomenon affects children who are neurologically and orthopedically typical. Unlike the typical developmental process of transitioning from heel strike at 18 months to a heel-to-toe pattern by age three, walking on the toes is not a normal stage. However, some consider toe walking as a typical variation that some children experience while learning to walk. This phase typically fades within three to six months after the child starts walking or by age seven. Nonetheless, toe walking has been observed even in adolescence and adulthood.

The Causes of Toe Walking Have Been Attributed To Various Factors Including:

- Congenital short tendo calcaneus
- Abnormal soleus muscle
- Unknown central nervous system defect
- Autosomal dominant inheritance with unequal penetrance
- Delayed maturation of the cortical spinal tract
- Normal transient phase of development
- Vestibular dysfunction
- Viruses

- Time spent in baby walking
- Habit

Despite the exact origin of toe walking of unknown cause being unknown, muscle biopsies of a group of 25 toe walkers' revealed common abnormalities in muscle fibres and related capillaries, suggesting an underlying neuropathic process. Toe walking is also observed frequently in children with cerebral palsy and muscular dystrophy. Additionally, it has been associated with:

- Autism
- Childhood schizophrenia
- Delayed language development
- Low IQ

Toe walking not associated with cerebral palsy is estimated to occur in 7% to 24% of the general childhood population.

IV. CLASSIFICATIONS

1. **Alvarez's Classification:** Alvarez's classification assesses the severity of toe walking based on the presence of ankle rockers.

   - **Type 1:** Presence of ankle rocker, absence of early third rocker, and predominant first ankle moment.
   - **Type 2:** Presence of ankle rocker (yes/no), presence of early third rocker (yes/no), and absence of predominant first ankle moment.
   - **Type 3:** Absence of ankle rocker and predominant first ankle moment, presence of early third rocker.

2. **Perry's Classification:** According to Perry, ankle kinetics is divided into three rockers. Toe walkers show alterations in these rockers.

   - **First Rocker:** Eccentric contraction of anterior tibia muscle during heel strike, leading to ankle plantar flexion.
   - **Second Rocker:** Eccentric contraction of gastrocnemius with dorsiflexion.
   - **Third Rocker:** Concentric contraction of gastrocnemius and soleus during push-off action.

3. **Pomarino Classification:** Pomarino categorized idiopathic toe walkers based on distinctive clinical traits:

   - **Type I:** Small triceps surae muscle causing toe walking; recognizable by heart-shaped calves, deep Achilles tendon creases, and forefoot fat deposit.

   - **Type II:** Positive family history, "V" signs above Achilles tendon, and gastrocnemius muscle hypertrophy.

- **Type III:** Heel support during walking; often resolves around ages 4-5, may persist in specific situations.

V. MEDICAL AND FAMILY HISTORY

The diagnosis of habitual toe walking is exclusionary, ruling out other causes like ankle equinus, cerebral palsy, or myopathy. A comprehensive medical and family history, gait analysis, musculoskeletal, and neurological exams are crucial. Prenatal, intrapartum, and postnatal histories are essential to exclude neuromotor disorders. Family history of toe walking is significant as it's seen to run in families.

1. **Evaluation of Toe Walking:** Differential diagnosis considers cerebral palsy and other encephalopathies. Specific characteristics can aid diagnosis, such as spasticity in cerebral palsy. Toe walking can also indicate conditions like autism, sensory dissociation, PDD, and Asperger syndrome. Careful examination of gait and family history aids diagnosis, ruling out other causes.

   Ankle rockers and kinetic changes can be indicators of toe walking severity. Diagnosis often necessitates exclusion of other disorders through comprehensive medical and family histories and thorough physical examinations.

Table 1: Three Gait Styles of the Equinus Are

1.	G1	A long progressive dorsiflexion followed by plantar flexion until toe-off. This pattern was more prevalent in old equinovarus feet, myopathies, and neuropathies.
2.	G2	Short-lived dorsiflexion with progressive plantar flexion until toe-off. This pattern was most common in Toe walking of unknown cause patients (up to 44% of all in the series).
3.	G3	Double bump pattern, short-lived dorsiflexion, short-lived plantar flexion, plantar flexion until toe off (Cerebral palsy pattern)

In the neuropathy group (GI), the entire triceps surae muscle contracted prematurely. However, this phenomenon is not initially evident in early toe walking of unknown cause (ITW) cases. The outcomes observed in patients with myopathy appear to be a consequence of compensatory mechanisms developed due to weak quadriceps, anterior tibial muscles, and triceps surae. The clinical observations noted in children with more advanced contractures were consistent with findings from all gait studies related to ITW. These gait studies yielded the following results:

Table 2: Gait Studies Findings

S.No	Gait Parameters	Degrees
1.	Mean anterior pelvic tilt	+ 6 degrees
2	Mean external hip rotation	+ 7.5 degrees
3	Peak Knee flexion	4.6 degrees
4	Peak dorsiflexion in stance	14.8 degrees
5	Dorsiflexion in swing	16.1 degrees
6	Foot Progression angle / External	+ 4.7 degrees

All the above findings are secondary to limited dorsiflexion. Adaptive external rotation of the hip and tibia occurs while attempting to place the limb in a more plantigrade position.

VI. GAIT EVALUATION

Gait analysis is a crucial step in evaluating and treating children who frequently walk on their toes. This process begins with careful gait observation. Since shoes can sometimes mask a child's natural walking pattern, it's important to analyse the child both with and without shoes. The following observations support the diagnosis of habitual toe walking, and these observations are made while the child is walking barefoot:

The child walks on their toes (balls of their feet) in a well-coordinated, balanced, and efficient manner.

While toe walking, the child maintains a normal angle and base of gait.
The child can run with minimal to no tipping or falling.
The child can walk both forward and backward easily while toe-walking.
The child can stand with their heels on the ground (full foot contact).

The child may take their first few steps in a heel-to-toe or full-foot contact fashion and transition to rise-to-toe walking only when increasing the speed of ambulation.

In conclusion, a child who habitually walks on their toes should exhibit gait observations similar to those of a normal, well-coordinated child who occasionally walks on their toes for a short period. The key difference is that a normal child will typically become fatigued while walking on their toes much earlier than a habitual toe walker. Gait analysis methods like tread mats and video recording can be helpful in making a diagnosis and assessing the progression of habitual toe walking. These techniques provide a permanent and objective record.

1. **Tread Mat:** A tread mat is a simple and cost-effective method to create a permanent record of a child's gait pattern. To create a tread mat, you will need:

    - A roll of dark-colored paper, approximately 20 inches wide.
    - Fine powder such as talc or plaster powder.
    - A can of hairspray to permanently affix the powder to the paper, if desired.

    The powder is placed at the end of a paper strip that is 15 to 25 feet long to create the tread mat. The child is then encouraged to walk along the mat after stepping in the powder. A powder imprint is left on the paper as the child walks or runs to the other end. By observing how the powder spreads on the paper, you can evaluate the amount of forefoot and heel contact in a child's habitual toe walking. The tread mat can also be used to assess the angle of gait, the base of gait, step length, and stride width.

2. **Video Gait Analysis:** Video gait analysis can be used to evaluate habitual toe walking and other gait disorders. This method allows for stop-frame and slow-motion evaluations of gait patterns. Straight-line comparison drawings can be created to compare measurements between visits, such as heel elevation at various phases of gait. This analysis provides a valuable resource for maintaining comprehensive records of treatment-related progress.

VII. PHYSICAL EXAMINATION

All patients with persistent toe walking as a major complaint should undergo a thorough musculoskeletal assessment. The static lower extremities examination of habitual toe walkers should reveal normal foot and leg alignment and appearance. There should be no obvious anomalies in the sagittal, transverse, or frontal planes, and no signs of muscle atrophy. Ankle dorsiflexion measurement requires special attention.

In a habitual toe walker, with the knee extended and the subtalar joint in a neutral position, there is often passive ankle dorsiflexion of at least 5 to 10 degrees. While some newly identified habitual toe walkers may have a slight ankle equinus, this appears to be an adaptation due to prolonged toe-walking. However, a large ankle equinus does not seem to be the primary cause of habitual toe walking. Regular toe walkers should exhibit normal neurological condition, with deep tendon reflexes, vibratory sensitivity, positional sensation, pain sensation, temperature sensation, and muscle power all within normal ranges, consistent with their age-appropriate neuromotor development.

Electromyographic investigations by Griffin et al. revealed that both habitual toe walkers and normal walkers engage their gastrocnemius and soleus muscles during the swing phase of toe-to-toe gait. Regular toe walkers showed higher amplitude and prolonged duration of tibialis anterior muscle activity during heel-to-toe gait. The habitual toe walker's electromyography gait pattern normalized following treatment with successive castings.

VIII. DIFFERENTIAL DIAGNOSIS

Early assessment of toe walkers is essential to differentiate habitual toe walking from other significant neuromuscular, psychiatric, and skeletal disorders that could cause different types of toe walking. Habitual toe walking is a diagnosis of exclusion, meaning it is diagnosed by ruling out other potential causes. Some of the conditions that need to be ruled out include cerebral palsy, pseudoscissor gait, and other neuromuscular disorders.

- **Cerebral Palsy:** Cerebral palsy is a non-progressive neurological disorder that can manifest before, during, or shortly after birth. It can cause various movement problems and gait abnormalities. The spastic type of cerebral palsy is most likely to result in a gait resembling toe walking. Children with cerebral palsy often exhibit delayed independent ambulation, increased muscle tone, hyperactive reflexes, and other neurological signs.

- **Pseudoscissor** Gait: Pseudo scissor gait is a variant of habitual toe walking that needs to be distinguished from the scissor gait pattern seen in cerebral palsy. Pseudo scissor gait occurs due to a combination of habitual toe walking and an adducted limb position, often caused by femoral ante torsion. Unlike cerebral palsy, children with pseudo scissor gait usually exhibit higher stability and may trip and fall frequently but do not show symptoms of spasticity or neuromata deficiency.

- **Mental Retardation:** Toe walking can sometimes be associated with mental impairment. Children with mental retardation may exhibit cognitive deficits, impaired social adaptation, behavioural issues, and physical symptoms such as hyper tonicity, ataxia, and seizures. Repetitive physical behaviours like head banging and rocking may also be present.

- **Autism:** Autism primarily involves emotional and behavioural challenges. Children with autism may exhibit behaviours such as isolation, anger when routines are disrupted, daydreaming, and sensitivity to criticism. While some children with autism may toe walk, it is often accompanied by other behaviours and characteristics associated with autism.

- **Diastematomyelia:** Diastematomyelia is a condition where the spinal cord is partially or completely divided by tissue in the spinal canal. Neurological deficits become evident around age two or three, affecting bladder and bowel control as well as gait. Foot deformities and anomalies in the lower extremities may also be present.

- **Muscular Dystrophy:** Muscular dystrophy, specifically Duchene muscular dystrophy and the mild limb-girdle type, can cause toe walking. Muscular imbalances and contractures lead to toe walking and a pointed foot posture. Temporal indicators are crucial in diagnosing muscular dystrophy and differentiating it from habitual toe walking.

  Each of these disorders presents with unique characteristics, and careful evaluation by a healthcare professional is necessary to make an accurate diagnosis and

determine the appropriate course of action. The differential diagnosis process involves ruling out these and other conditions to arrive at the correct diagnosis of habitual toe walking.

IX. GASTROCNEMIUS SOLEUS MUSCLE EQUINUS

This refers to a condition where the calf muscles (gastrocnemius and soleus) are tight, leading to limited ankle dorsiflexion. This can result in toe walking. The Silfverskiold test is used to assess this condition. If limited dorsiflexion is present both when the knee is flexed and extended, it could indicate a combined gastrocnemius-soleus muscle equinus. Children with this condition might also show features like knee hyperextension (genu recurvatum), midtarsal pronation (flattening of the arch of the foot), and an abducted stance angle (positioning of the feet) when standing. Their gait might also be bouncy due to early heel lift-off.

1. **Type I Genetic Sensory Neuropathy:** Children with this neuropathy can present with a toe walking pattern. These children might be misdiagnosed as idiopathic toe walkers. They could have clawed hands, clawed feet, and hypotrophy (muscle wasting) of the calf muscles. This condition is linked to neuropathy and has been described in limited case studies.

2. **Mc Ardle Illness:** Kids with Mc Ardle illness, a type of muscular disorder, might also toe walk. Their girdle muscles can be hypo trophic, the forefoot might be wider, and their calf muscles could have a different appearance due to muscle changes. However, the reasons behind toe walking in these cases are not fully understood and require further research.

These conditions highlight the complexity of diagnosing the underlying causes of toe walking in children. Proper evaluation, often involving medical professionals, is crucial to accurately diagnose and treat the root cause of toe walking in each individual case.

The management of toe walking of unknown cause (ITW) in children without a definitive diagnosis is a subject of considerable debate. While conditions like cerebral palsy, myopathies, and neuropathies are treated with physical therapy, exercises, bracing, casts, Botox, and sometimes surgery, the approach to "normal" children with ITW remains uncertain.

Non-operative methods for ITW appear to offer no more benefit than mere observation, based on anecdotal accounts and limited literature reviews. This is due to the premature firing of the calf muscles (gastrocnemius and soleus) seen in ITW, which hinders the normal functioning of the anterior tibial muscle. Older children beyond the age of five respond less effectively to non-operative treatment. However, positive outcomes are more likely in younger children aged 3 to 5 with mild ankle dorsiflexion restrictions. Surgical intervention is considered when concerns about uncorrected sensory issues causing recurring deformities and further loss of ankle dorsiflexion arise.

Over 50% of ITW cases respond to therapies like physical therapy, bracing (daytime or night-time), Botox, and corrective casts. Younger children show better long-

term results when treatments are consistently maintained for two to four growth cycles. Sustained stretching of the calf muscles over 1-3 years of growth is necessary for lasting improvement in contractures and restoration. The tension on the muscle-tendon complex needs to be constant to maintain proper anterior tibial function and accommodate tibia and fibular growth.

Recent orthopaedic research suggests that surgery is the most effective strategy for children with ITW who do not respond to non-surgical treatments. Studies on a specific group of ITW patients struggling with non-surgical interventions showed improved ankle motion after procedures like Vulpius-type releases or Achilles tendon lengthening. However, full recovery of plantar flexion power was not consistently observed.

Caution against prolonged delays in treatment is advised due to potential complications like osteochondritis dessicans and increased lumbar lordosis. If non-operative treatments fail, surgical intervention is often the most reliable option. Thorough pre-treatment evaluation is crucial for accurate diagnosis, and gait analysis during key treatment phases is beneficial.

Habitual toe walking, though often considered a developmental phase, can lead to discomfort and instability, with internal limb rotation abnormalities causing tripping and falling. Accelerating the transition from toe walking to heel-toe gait is essential and may prevent structural ankle equinus resulting from chronic toe walking. Various methods such as orthotics, serial casting, cognitive muscle management, shoe modifications, and surgery have been used to address habitual toe walking.

For instance, shoe therapy involves wearing rigid-soled, straight-last shoes that restrict dorsiflexion at the metatarsal-phalangeal joint. High-top shoes and heel lifts can be incorporated. Orthotic prescriptions like heel lifts, gait plates, and ankle-foot orthoses are used to address habitual toe walking. Auditory feedback techniques have shown promise in reducing toe walking. Surgical intervention, specifically Achilles tendon lengthening, is considered when significant structural equinus is proven.

Observation is vital to identify intervention needs and track ankle dorsiflexion limitations. Stretching activities are recommended if dorsiflexion is reduced. For children with good ankle dorsiflexion range of motion, therapies such as gait re-education and motor control interventions are beneficial. Auditory feedback techniques aim to establish normal gait patterns, and footwear treatment restricts dorsiflexion at the metatarsal-phalangeal joint.