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Long-term gait outcomes following conservative management of idiopathic toe walking

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ABSTRACT

Background: Idiopathic toe walking is a diagnosis of exclusion characterized by a persistent toe–toe gait pattern after three years of age. Treatment for toe walking includes physical therapy, orthotics, casting, Botulinum Toxin A injection into gastrocnemius/soleus muscles, and/or surgery; yet, little evidence exists regarding long-term treatment effects.

Research question: The objective of this study was to explore the differences in longer-term gait outcomes and severity of idiopathic toe walking between children treated actively with casting or inactively following recommendations for stretching.

Methods: Forty-three adolescents and young adults (14.3–28.8 years; 21 females, 22 males) who had participated in an idiopathic toe walking classification study as children, returned for repeat physical examination and three-dimensional computerized gait analysis (13.4 years follow-up, range 9.4–17.8 years); 23 participants had received active treatment with casting and ankle foot orthotics ± Botulinum Toxin A injection as children and 20 participants had received inactive treatment with recommended stretching exercises. Gait analysis data were compared retrospectively from baseline to follow-up using analysis of variance; toe walking severity was compared using a Wilcoxin Signed-Rank Sums test.

Results: Ankle angle at initial contact, peak dorsiflexion in stance, and toe walking severity improved significantly in the active treatment group only at follow-up. Significant improvement in peak ankle power and timing of ankle kinematics and kinetics in the gait cycle were found in both groups; however, greater changes occurred in the active treatment group. Both groups showed significantly improved internal plantar flexor moments, whereas knee extension increased in stance and passive ankle dorsiflexion decreased in both groups at follow-up ($p = 0.001$). Intermittent toe walking was reported in 49% (21/43) of participants at follow-up.

Significance: The results of this study suggest that improvement in ankle kinematic timing and ankle kinetic gait analysis variables is sustainable, independent of conservative treatment for idiopathic toe walking in childhood.

1. Introduction

Idiopathic toe walking (ITW) is a condition characterized by a persistent bilateral toe–toe gait pattern and diagnosed by exclusion of other known pathology. Toe walking may emerge with early ambulation, but is considered abnormal in typically developing children after the age of three years [1,2], with an estimated prevalence of 4.9% by 5.5 years of age [3]. Pain in the legs or feet and frequent tripping or falling may present with this condition [2,4]. Further, limited ankle dorsiflexion (DF) passive range of motion (PROM) may predispose children to ankle injuries [5]. These clinical manifestations of ITW are conceptualized as impairments in body functions and structures in the International Classification of Functioning, Disability and Health (ICF) and may cause restrictions in daily function [6]. There are limited ITW studies considering activity levels and/or participation components of the ICF; this is concerning as toe walking does not necessarily resolve with treatment [7,8].

There is no clear etiology for ITW, making it difficult to determine if treatment needs to target toe walking, motor/sensory issues, or if it only has an impact on ankle PROM [7–9]. Management options for ITW typically include stretching, orthotics, serial casting (with or without Botulinum Toxin A injection [BoNT-A] to the gastrocnemius/soleus

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muscles), and/or surgery [9]. A systematic review comparing casting and surgical treatment in children with ITW identified 10 studies investigating improvements in ankle DF PROM and/or toe walking over an average of five years with only the effects of surgery sustainable for more than one year [7]. Other studies have shown that injecting BoNT-A prior to casting [10] or conservative treatment (footwear, night splinting, and stretching) [11] does not improve the outcome of either cast-only or conservative-only treatment one to two years post-intervention. Some studies have focused on the natural history of toe walking including two studies that found persistent toe walking in inactively treated children over three to five years [12,13] and one small sample size study that found 73% resolution of toe walking following stretching exercises ± orthotics or night splints over an average of 14 years [4].

Importantly, few studies have explored longer-term gait outcomes of toe walking more than five years following treatment in childhood [4,12,14,15]; interpretation of their results are limited by small sample size [4,14,15], lack of pre-treatment data for kinematics [15] or level of ITW severity [4,12,15]. Given the dearth of evidence and inconsistent findings on gait changes over five years in this population, the primary objective of this study was to explore differences in longer-term gait outcomes and severity of ITW between children treated actively with casting and ankle foot orthotics (AFOs) or treated inactively following recommendations for stretching. Additionally, capacity for activities and participation was examined at follow-up to consider long-term functional consequences.

2. Materials and methods

2.1. Participants

Approval for this project was obtained through the local institutional Ethics Board. Participants were recruited via information letter and follow-up phone call through the Gait Lab database at our tertiary care rehabilitation center and were part of a cohort of 133 children who participated in an ITW classification study from 1997 to 2005 [16]. Participants who met the inclusion criteria for the original study (4–16 years of age and diagnosis of ITW) were excluded from follow-up if they had since received a change in diagnosis from their physician, thus ruling out an idiopathic origin. Of the original 133 children, 48 could not be contacted, 33 declined (cost of travel: $n = 1$; too busy: $n = 8$; unable to travel: $n = 10$; no reason given: $n = 14$), six were not included due to change in diagnosis, and one was deceased. A convenience sample of forty-five adolescents and young adults gave informed consent and completed follow-up gait analysis study. Two participants' data sets were removed; one due to an incomplete baseline assessment and one who had been treated surgically, leaving 43 participants in the study. No additional intervention was provided. No participants were receiving treatment at the time of follow-up.

2.2. Procedures

Parent and/or participant interview, lower extremity physical examination, body mass and height measurement, retro-reflective marker and surface electromyography (EMG) electrode placement on participants' skin, and instrumented gait examination were completed retrospectively in the Gait Lab at baseline (1997–2005) and prospectively at follow-up (2015–16). Participants completed either the Pediatric Outcomes Data Collection Instrument (PODCI) (adolescents; 11–18 years of age) or the Medical Outcomes Study 36-Item Short Form Survey Instrument (SF-36) (young adults over 18 years of age) to assess current activity limitations or participation restrictions [17,18]. This study used a conventional marker set and modified multi-segment foot model that has undergone test-retest reliability trials to determine intra-rater and inter-rater repeatability in the Gait Lab [19]. Two physical therapists performed all physical examinations, marker and EMG placement; one in the baseline study and one at follow-up.

Baseline data were collected as described by Alvarez et al. [16]. At follow-up, the Gait Lab physical therapist and biomechanist were blinded to participants' baseline gait data, ITW severity classification, and physical examination. Intervention status was confirmed by medical record review following data processing. The conventional Helen Hayes marker set [20] used at baseline and a modified multi-segment foot model [21] were used to guide placement of 63 retro-reflective markers on participants' skin [19,22]. Wireless surface EMG electrodes (Delsys Incorporated, Natick, MA) were placed over tibialis anterior, medial gastrocnemius, rectus femoris, and semitendinosus/membranosus muscles using protocols described by Basmajian and Blumenstein [23]. One static standing trial was conducted before the walking trials to determine joint center positions of rotation for the hip, knee, and ankle and to define lower limb segment axes. Three-dimensional position of the markers was tracked at 120 Hz with a 12-camera motion capture system (Motion Analysis Corporation, Santa Rosa, CA) while participants walked at a self-selected typical pace along a ten-meter walkway. Ground reaction forces were collected at 1200 Hz simultaneously from three floor-embedded force plates located in the middle of the walkway (Advanced Mechanical Technology Incorporated, Allentown, MA). Participants repeated walking trials until 10 clean force plate strikes were collected for each limb; three consistent strides from three different trials were selected for analysis and averaged [16,19]. Representative trials were determined by visual inspection of all traces. Data were processed using Visual 3D (C-Motion, Germantown, MD) and custom MatLab code. The change from OrthoTrak 6.2 Software (Motion Analysis Corporation, Santa Rosa, CA) used at baseline to Visual 3D software was designed around OrthoTrak guidelines for backwards compatibility, proven comparable within the Gait Lab data. EMG threshold was calculated as reported by Alvarez et al. [16].

2.3. Data analysis

Gait data analyses were conducted using IBM SPSS Statistics for Windows, Version 23 (IBM Corp., Armonk, NY). Analysis of variance (ANOVA) was used to compare the primary outcome measure of peak ankle DF during stance at baseline and at follow-up. ANOVA was repeated for supporting continuous kinematic and kinetic variables and ankle DF PROM. The ANOVA was a 2×2 mixed effects design with a third factor; it consisted of one between-subject factor of treatment effect and two within-subject factors of time (baseline and follow-up) and side (right and left). The main effects of treatment, time, and interactions of treatment from baseline to follow-up were determined. The main effect of side was disregarded in the analysis as the differences in sides were simply used to account for twice the data to avoid violating the assumption of independence [24,25]. ITW severity was compared from baseline to follow-up using a Wilcoxin Signed-Ranks Sum test to accommodate for the ordinal variable of severity classification.

3. Results

Twenty participants received inactive treatment following baseline assessment with a recommended stretching program to maintain DF PROM. Twenty-three participants received active treatment following baseline assessment; all but three of them received treatment within one year of their baseline assessment, two received treatment within two to three years, and one received treatment six years' post-baseline with mean follow-up after treatment of 12.1 years (standard deviation, SD, 3.1). In the active treatment group, six participants received serial casting for six weeks with a change in cast after three weeks and 17 participants received BoNT-A injections prior to the same serial casting protocol; all 23 participants wore AFOs for one year following cast removal. Participants were treated by one of two pediatric orthopedic surgeons. No participants reported a lack of adherence to intervention.

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