International Journal of Clinical Trials
*Besios P et al. Int J Clin Trials. 2024 Aug;11(3):231-239*
http://www.ijclinicaltrials.com
pISSN 2349-3240 | eISSN 2349-3259
DOI: https://dx.doi.org/10.18203/2349-3259.ijct20241591

**Systematic Review**

# Conservative therapy and physiotherapy in children with toe walking: a systematic review

**Panagiotis Besios[1]*, Georgios M. Kyriakatis[2], Thomas Besios[2]**

[1]Department of Physiotherapy, University of Patras, Patra, Greece
[2]Human Performance and Rehabilitation Laboratory, Department of Physiotherapy, School of Health Sciences, University of Thessaly, Lamia, Greece

**Received:** 04 May 2024
**Accepted:** 24 May 2024

***Correspondence:**
Panagiotis Besios,
E-mail: panosbesioss@gmail.com



## ABSTRACT

The purpose of this systematic review was to study all the randomized controlled trials on the effects of conservative treatment and physiotherapy programs on children with toe walking. A literature search was performed in the databases: PubMed, Scopus, PsychInfo, SportDiscus, and ResearchGate. Toe-walking and toe walking were the keywords searched. Furthermore, explicit inclusion and exclusion criteria were established, and the research selection procedure was carried out by two distinct reviewers. The physiotherapy evidence database (PEDro) scale was used to assess the quality of the final studies included in the systematic review. Out of the total of 2079 studies initially identified, 6 studies were finally included. The results showed that physiotherapy interventions and conservative therapy, such as botulinum toxin, ankle foot orthosis or foot orthosis and electric stimulation therapy can help reduce toe walking especially when these methods are combined with classic physiotherapeutic exercises and stretches. Conservative treatment and physiotherapy have positive effect on children who have toe walking symptoms. However, further research is needed in this area to determine the most effective treatment methods to reduce the symptoms of toe walking and find the best treatment to improve the daily lives of these patients, focusing on avoiding surgical procedures.

**Keywords:** Toe-walking, Botulinum toxin, Ankle foot orthosis, Foot orthosis, Electric stimulation therapy

## INTRODUCTION

Toe walking (TW) is a pathology that affects a large number of children, leading them on a pattern of walking that their heels are not touching the ground. TW was spontaneously healed in 59% of children without equinus contractures (inability to raise the foot up to a neutral posture) by the age of 5.5 years, and 79% by the age of 10 years.[1]

TW can be caused by several neurologic and developmental abnormalities (neurologic, orthopedic, neuromuscular, or neuropsychiatric conditions) and most of them are idiopathic TW (ITW) which may be the first sign of a development problem. More specifically, cases that lack a definitive etiology are categorized as ITW.[2] ITW affects males more than girls and about 4.5% of the population and it also occurs in normally developing adolescents who are otherwise healthy.[3]

The Clinical Practice Guideline in Development group of Academy of Pediatric Physical Therapy (APTA), focusing on ITW, recommends a differential diagnosis process to optimize early intervention and outcomes. PT interventions and medical interventions differ based on the etiology of TW. The differential diagnosis process affects the PT interventions chosen based on the specific etiology, severity and prognosis thus, impacting successful outcomes.[4]

The extent literature on TW is characterized with examples of interventions based on a careful history and clinical exam prior to determining the most appropriate treatment for children. In general, most recent studies focus on a population, intervention, control, and outcomes (PICO) question that indicates a specific etiology so that a clinician can compare the child in front of them with specific recommendations. The specific focus of these studies underscore the recognition that different etiologies reflect an array of tissue biomechanics, and varying types of motor control that impact prognosis and outcomes. For example, in cerebral palsy (CP), focusing on TW without the context of tissue flexibility, type of CP, kinematics and kinetics of gait, bony alignment and structure is less likely to be successful in achieving gait outcomes. Similarly, the natural history of stiffness of the gastric-soleus complex in Duchenne's muscular dystrophy impacts when and how it is addressed to maintain function. Additionally, parents report that their experience in finding a treatment for their child with ITW as confusing with different practitioners providing varying recommendations.[5] As practitioners being sensitive to this need necessitates an awareness of what are the likely treatments for the specific child in front of us based on the current state of the evidence. This again points to using etiology as a starting point in our clinical decision-making followed by a PT thorough examination.

According to a study, motor impairments appear in the beginning stages of life but may also develop prenatally, i.e. throughout the early and late fetal phase.[6] TW is a significant motor difficulty, with 8.4% of autism spectrum disorder (ASD) patients walking on the balls of their feet, with no contact on the heels and the ground.[7] Children with ASD exhibit significantly greater mobility in their joints, greater gait abnormalities and walk almost two months later compared to the normal children.[8] Researches showed that children with TW and ASD need a longer duration of physical therapy intervention.[9]

CP is an umbrella term referring to movement impairments caused by injury to the central nervous system.[10] Children with CP have flat caused of the reduced plantar activity in the second part of the swing phase.[11]

Muscular dystrophy is a genetic condition with several variants. Each has its unique genetic pattern, onset duration, and rate of muscle loss and weakness. Different forms of this medical condition are caused by changes in particular genes.[12] These children are not able to walk like other children at this age and the fall of risk and TW being a very common condition.

Conservative therapies are typically used to treat young children who do not have a restriction in ankle dorsiflexion. Conservative options for treatment include monitoring, orthotics, special shoes, splints, calf muscle stretching, and serial casting. Another conservative treatment is botulinum toxin A (BTX-A) injections into the calf muscles, or a combination of BTX with serial casting and physical therapy.[13,14]

Physiotherapy plays a crucial role in addressing TW in children due to its multifaceted approach in assessment, intervention, and long-term management. Firstly, physiotherapists are skilled in conducting comprehensive assessments to identify the underlying causes of toe walking, whether they stem from neurological, orthopedic, neuromuscular, or neuropsychiatric conditions. This enables tailored treatment plans based on the specific needs of each child, considering factors like severity, prognosis, and individual differences. Secondly, physiotherapy interventions encompass a wide range of techniques aimed at addressing musculoskeletal imbalances, improving range of motion, strengthening muscles, and enhancing motor control. These interventions not only target the immediate issue of toe walking but also aim to prevent secondary complications and promote optimal functional outcomes. By providing early intervention and ongoing support, physiotherapy plays a vital role in maximizing the potential for improved gait patterns and overall quality of life in children with TW.

The purpose of this systematic review was to study all the randomized controlled studies on the effects of conservative treatment and physiotherapy programs on children with TW.

## METHODS

This systematic review was registered in International prospective register of systematic reviews (PROSPERO) system and was conducted according to the preferred reporting items for systematic reviews and meta-analyses (PRISMA) 2020 guidelines and flowchart.[15]

### *Eligibility criteria*

Specific databases, keywords and eligibility criteria were selected for the systematic review. The inclusion criteria were studies: published between 2013-2023, published in English, RCT studies, that the participants were pediatric population (<18 years old) diagnosed with TW due to underlying or non-pathology (idiopathic), that conservative treatment (AFO, botox, physical therapy) for TW has been selected as an intervention, and that the sample was evaluated with reliable and valid measurement tools for the variable in question. On the other hand, the exclusion criteria were studies: case-control type, pilot type, that had chosen surgical treatment as the type of intervention, and that were a secondary analysis of another study or protocols for a future study.

### *Information sources, search strategy and selection process*

The literature search was conducted in PubMed, Scopus, PsychInfo, SportDiscus and ResearchGate databases on March 29, 2023. In addition, all databases used the 2013-2023 date restriction before the final search records were displayed. The keywords used were toe walking and toe-

walking, creating the following search capture across all databases: "toe walking" OR "toe-walking".

Eligibility of the studies was performed by two separate reviewers with the possibility of a third person consent in case of disagreement between the first two, however the main reviewers were in full agreement with the final studies of this systematic review. The evaluation was based, after removing duplicate studies, on the titles, abstracts and finally, from the full text of the articles, based on the above inclusion and exclusion criteria.

### *Data collection process and data items*

Data from the studies were extracted by both main reviewers separately, who were guided by the information provided by the authors of the studies. Therefore, the data extracted included: the characteristics of the participants (age, gender, condition), the type of intervention (orthotics, botulinum toxin, electrotherapy) and its parameters (duration of the intervention, duration and number of sessions), and the type of the outcome measure (the measurement tool in question), as well as the number and time of each different assessment.

### *Quality assessment of the trials*

The final studies in the review were assessed by the physiotherapy evidence database scale (PEDro) scale.[16] The scale assesses the methodological quality of studies for adherence to quality criteria and risk of bias. It consists of 11 items, of which the first is for external validity and the others for internal validity. Each of the items assessing internal validity is scored with 1 point. In this way, the quality of each study can be classified as low (PEDro score 0-4), fair (PEDro score 5-6) or high (PEDro score 7-10).

Each article was assessed separately by the two main reviewers. It should be noted that in the studies where there was no randomization of the sample into groups, but it was chosen a randomization system of interventions, the reviewers had agreed and decided to score the scale items related to the groups of the study in question as zero, i.e. without giving them any score.[17,18]

## RESULTS

### *Study selection*

The initial records after searching the databases were 2079. After removing duplicate studies 1335 remained and after checking the titles of the articles 67 studies remained for checking their abstracts against the eligibility criteria. Only 33 were selected for full text screening, of which 6 met the inclusion criteria set by the researchers and were finally included in the qualitative synthesis of the systematic review. The process of screening the studies is also graphically illustrated with the PRISMA 2020 flowchart in Figure 1.

### *Study characteristics*

Of the 1335 studies initially identified, only 6 met the inclusion criteria set for study eligibility and most of them were RCTs, making the results of the systematic review qualitatively superior. Of the included studies, 1 was carried out in Sweden, 1 in the USA, 1 in Australia, 1 in Finland, 1 in Pakistan and 1 in India. A total of 175 participants have taken part in all the studies, with the majority of them being male. The trials therapies included BTX, foot orthoses, electrical stimulation (ES) and physiotherapy. The intervention duration of the studies ranged from 6 weeks to 24 months, and the instruments used to measure and assess TW were the 3D gait analysis in 2 studies and the goniometer in 2 studies. Finally, the other 2 studies used the handheld dynamometer, L-test of functional mobility, the ITW severity scale, lower extremity function test, pain visual analogue scale, GaitRite, weight bearing lunge test and an intelligent device for energy expenditure and activity system.

The detailed characteristics of the design, sample, assessment, intervention and results for each study are shown in Table 1. It should be noted that in the following studies we are not taking into account participants who "dropped out" later, and as a result these characteristics do not account for the final sample size, so we present these approximate values.

### *Quality of studies*

Regarding the quality of the 6 studies that were finally included in the systematic review, their assessment using the PEDro scale showed that 4 studies have a fair level of methodological quality, while the remaining 2 have a low level. The mean score of the included studies based on the PEDro scale is 4.5, giving an average methodological level of the studies in the systematic review and average effective evidence in general of the selected intervention forms. Information on which specific validity criteria are found in each study is given in Table 2.

### *Effectiveness of the interventions*

All of the studies reviewed and analyzed in this systematic review had clear results regarding their positive or non-positive effect on TW and ITW. More specifically and more summarized for BTX Treatment, adding BTX-A injections prior to cast treatment for ITW does not improve the outcome of cast-only treatment.[19] In the evaluation of the second article that BTX injections was applied combined with conservative therapy but also with night splints the most prominent change in ITW pattern was noted during the first 12 months after the introduction of the treatment and the BTX group seemed to reach the goal earlier but have adding BTX injections did not significantly enhance the goal to walk either flat foot or with heel strike at 24 months posttreatment.[20]

**Table 1: Description of the design, intervention, results, sample and assessment characteristics of each study.**

| Study | Design | Sample | Assessment | Methods | Results |
|---|---|---|---|---|---|
| **Engstrom et al[19] (2013)** | RCT | 47 idiopathic toe walkers - casting treatment (CA) group (n=26): [♀=13, ♂=13, MA=9.4]; casting and botulinum toxin A (CA + BTX) group (n=21): [♀=5, ♂=16, MA=9.4] | 3D gait analysis, passive ROM of the hip, knee, and ankle joints (goniometer), ankle dorsal extensor strength (handheld dynamometer). Before treatment and after 3 and 12 months. | CA group: bilateral below-the-knee walking circular casts extending from the toes to the proximal part of the calf (ankle in neutral position), 4 weeks. CA + BTX group: bilateral treatment with 12 units/kg body weight of botox, 4 injections in each calf (2 in the proximal third of the lateral and medial gastrocnemius bellies, 2 distally in the gastrocnemius-soleus complex). This group received the same casts 1 - 2 weeks after the injections. Both groups: after cast removal they were given oral and written instructions by a physiotherapist to perform calf-muscle stretches 5 times/ week and walk on their heels at least 50 steps/day. | No statistically significant results in any gait parameter. ↑ of ankle passive ROM in both groups ($p<0.001$). No changes in hip or knee motion. ↑ ankle dorsal extensor strength in both the CA group (3 months - $p=0.01$, 12 months - $p=0.03$) and the CA + BTX group (3 months - $p=0.01$, 12 months - $p=0.001$), but with no differences between them. |
| **Herrin et al[21] (2015)** | RCT | 18 idiopathic toe walkers - MA=5±1.4, AFO group (n=9): [♀=4, ♂=5], FO group (n=9): [♀=4, ♂=5] | 3D gait assessment, L-test of functional mobility. At baseline, 6 and 12 weeks of treatment. | AFO group and FO group: they wore the orthotics all the time for 6 weeks except for sports activities and sleeping. They walked at their normal pace along a 10-m walkway for five trials while gait kinematics were recorded. | No statistical differences were seen between groups about functional mobility, ankle ROM and walking time. AFO group walked significantly faster at 12 months ($p=0.006$). Only the FO group sustained the improvement at follow-up ($p<0.001$). |
| **Sätilä et al[20] (2016)*** | RCT | 29 idiopathic toe walkers - conservative (CO) group (n=13): [♂>♀, MA=4.9], botulinum treatment (BTX) group (n=16): [♂>♀, MA=5.3] | TWSS, active and passive ankle ROM, LEFA. At baseline and 6, 12, 18, and 24 months posttreatment. | CO group: 12 children wore indoor shoes with a firm heel cup and straps daily and night splints 5 nights/week, home stretching program performed 5 days/week, for a minimum of 10 minutes/day. 1 child did not wear night splints and firm shoes regularly but did the stretching program. All the children did a physiotherapy program (once/week) and three of them wanted BTX-A treatment: one patient had BTX-A therapy at 12 months, another at 6 and 12 months, and a third at 12 and 18 months. BTX group: all the children did the same conservative treatments. 16 children worn firm shoes, night splints, performed a home stretching program, physiotherapy (once a week) and injections in calf muscle with BTX-A. All 16 patients received BTX-A treatment at baseline, 8 | ↓ of toe walking in both groups with no statistically significant results or differences. BTX group changed the walking pattern earlier. No statistically significant differences from baseline in ankle ROM in both groups. ↑ in lower extremity function was noted during the first 6 months in both groups ($p=0.002$), but not between them. |

Continued.

| Study | Design | Sample | Assessment | Methods | Results |
|---|---|---|---|---|---|
| | | | | received a second treatment at 6 months and 1 received a third treatment at 12 months. | |
| **Izhar et al[17] (2018)** | RCT | 50 children with toe walking (unilateral or bilateral), CP, development delay, muscular dystrophy or post traumatic conditions: (3–12 years old) | Goniometry, pain (VAS), difficulty in walking and ADLs. At baseline and 3 months post-treatment. | Therapeutic exercises once a day and advised to wear AFOS 12 hours a day. | Significant difference (p=0.001) in the variables of cadence, pain and ankle total ROM (p<0.005). |
| **Mukhop adhyay et al[22] (2018)** | RT | 16 children with spastic cerebral palsy - electrical stimulation (ES) intervention group (n=8): [5–14 years old], control group (n=8): [5–14 years old] | Gait data (intelligent device for energy expenditure and activity system). Before and after the intervention (12 weeks) | ES group: multichannel stimulator with a pair of surface stimulating electrodes for 30 minutes/day, 5 days/week. Also, they received conventional physiotherapy exercises for 30 minutes/day, 5 days/week. Control group: conventional physiotherapy exercises for 60 minutes, 5 days/week. | ↑ of gait speed, (p=0.02), heel strike (p=0.000), flat foot (p=0.005), swing power (p=0.03) and ground impact (p=0.003) in the ES group. ↓ of stride length (p=0.04) in the ES group. |
| **Michalit-sis et al[18] (2019)** | RCT | 15 idiopathic toe walkers: [♂=10, ♀=5, MA=6] | GaitRite, WBL test, gait velocity, cadence, stride length and time, stride width, stance and swing percentage, foot progression angle and double support time. | Condition 1: barefoot, condition 2: usual school or play footwear, condition 3: custom made rigid contoured carbon fiber foot orthoses and footwear (combined) | ↑ heel contact (p=0.021) in the combined treatment only. ↑ stride time in the combined treatment condition compared to barefoot walking (p=0.006). ↓ in the percentage of swing phase in the gait cycle (p<0.01), ↑ in stance phase (p<0.01) and ↑ in double support time (p<0.001). |

RCT= randomized controlled trial, ↑=increase, ↓=reduction, n=sample number, MA=mean age (in years), mA=milliampere, *=approximate sample data, ≈ =approximate, TWSS=toe-walking severity scale, 3D=three dimensional, CA=casting, BTX=botulinum toxin, AFO=articulated foot orthosis, FO=foot orthosis, ROM=range of motion, LEFA=lower extremity function test, VAS=visual analogue scale, ADL=activity of daily living, ES=electrical stimulation, TS=tightness, WBL=weight bearing lunge

**Table 2: Assessment of the methodological quality of the studies for adherence to quality criteria and risk of bias based on the Pedro scale.**

| Study | 1* | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | Score | Quality level |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Engstrom et al[19] (2013)** | ✓ | ✓ | ✓ | ✓ | - | - | - | ✓ | ✓ | ✓ | - | 6/10 | Fair |
| **Herrin et al[21] (2015)** | ✓ | ✓ | ✓ | ✓ | - | - | - | ✓ | ✓ | ✓ | - | 6/10 | Fair |
| **Sätilä et al[20] (2016)** | ✓ | ✓ | ✓ | ✓ | - | - | - | ✓ | ✓ | ✓ | - | 6/10 | Fair |
| **Izhar et al[17] (2018)** | ✓ | ✓ | - | - | - | - | - | - | - | - | ✓ | 2/10 | Low |
| **Mukhopadhyay et al[22] (2018)** | ✓ | ✓ | - | ✓ | - | - | - | ✓ | - | ✓ | ✓ | 5/10 | Fair |
| **Michalitsis et al[18] (2019)** | ✓ | ✓ | - | - | - | - | - | - | - | - | ✓ | 2/10 | Low |

Each number in the first row of the table refers to the corresponding criterion of the scale, (*the first criterion is not included in the final score, - the criterion was not met, ✓ the criterion was met)

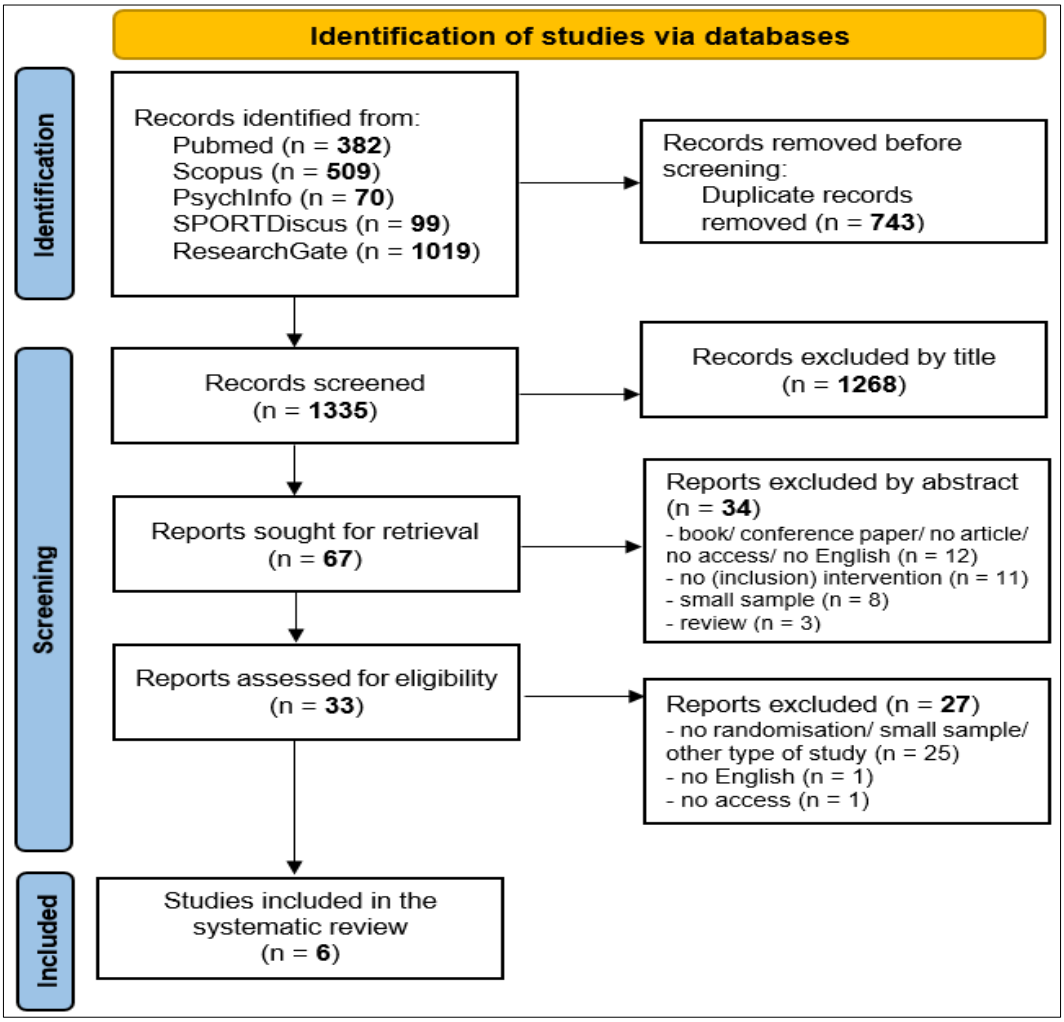


**Figure 1: Graphical illustration of the search process and the final selection of studies with the flowchart.**

Furthermore, the effectiveness of orthotics in reducing or improving toe walking was relatively positive and improved local dynamic stability and awareness of foot position with increased sensory feedback provided throughout the length of the foot.[18] Ankle foot orthosis (AFOs) orthotics with physiotherapy exercises improved ankle function and range of motion in children with ITW.[17] Finally, it should be noted that in one article, children parents preferred the foot orthosis (FOs) for donning and appearance in addition of the AFOs with similar out-of-brace effects.[21]

On the other hand, the use of ES therapy for ITW correction showed significant statistical increase in gait speed, initial contact (heel strike), flat foot position (loading response), in the swing power, ground impact and decrease in stride length resulting in improvement of body balance confirming a reduction on TW. The results indicate that ES therapy along with conventional physiotherapy may correct the toe-walking gait in children with spastic hemiplegic cerebral palsy.[22]

We observed in the BTX and conservative treatment interventions that stretching exercises (calf muscles, 5 times/week) were used in both groups, with a result of increasing passive ankle range of motion (ROM) and the pattern of ITW in both groups and statistically significant increasing lower extremity function.[19,20] Physical therapy exercises only or in combination with another approach, improved TW.[20] AFOs combined with exercise on children with ITW had a statistically significant increase in ankle dorsiflexion ROM which resulted in the correction of walking pattern of children with ITW.

## DISCUSSION

So, all the methods that were applied, both AFOs and botox, as well as ES, had positive results in reducing toe walking as well as in the overall clinical picture of the children.

More specifically, interventions with AFOs and FOs for the rehabilitation of ITW had positive results: reduced pain, increased ankle total ROM, heel contact, length of stride and double stance time. These results are supported by a similar study that examined the effectiveness of serial casting and AFOs in treating toe walking on children with autism spectrum disorder. The results showed that all

participants improved ankle dorsiflexion walking following 6 months of using AFO.[23] Another study that supports our findings had 21 kids that took part in the research after being given an ITW diagnosis. The participants walked in both bare feet and while wearing AFO. Step cadence was decreased, step length, stance phase, and stride duration were all increased while wearing AFO. These results show that the use of AFO could help the management of ITW by avoiding toe walking in children and so reducing its negative effects.[24]

Also, another study came to confirm our findings with patients wearing the orthosis 24 hours a day for the first six weeks of therapy, only removed during sleeping and procedures like sports or physiotherapy. After the initial 16-week period, patients were free to adjust the wearing time of the orthosis to their own needs with results being really encouraging and after 12 months, 73% of patients had normalized their gait, this outcome can only offer a general indication of treatment success.[25]

Regarding the use of BTX therapy the results of the intervention were positive such as increase of ankle dorsal extensor strength, ankle passive ROM and decrease of ITW. A study that confirms our findings was involved 23 participants that wore casting and ankle foot orthotics with the use of BTX while another group of 20 participants had received inactive treatment with recommended stretching exercises.[14] Ankle angle at first heel strike, peak dorsiflexion in stance, and toe walking severity improved considerably in the group of the BTX use. Both groups also had significant improvements in peak ankle power and the timing of ankle kinematics and kinetics during the gait cycle, however, the active therapy group (BTX) experienced bigger changes. At follow-up, both groups had significantly better internal plantar flexor moments, although knee extension increased in stance and passive ankle dorsiflexion reduced (p=0.001).

Also, another research is added that reinforces the opinion about the usefulness of botulinum toxin with children with ITW treated with incobotulinumtoxin A injection in the gastrocnemius medialis/lateralis muscles. In some children, incobotulinumtoxin A injection enhanced maximum passive ankle dorsiflexion, and the benefit lasted up to 6 months. There were no documented side effects from incobotulinumtoxin A injection. In comparison to cerebral palsy, therapy with incobotulinumtoxin A may increase maximum passive ankle dorsiflexion and is safe and well-tolerated in ITW with a longer-than-expected impact.[26]

In our included study of the use of ES intervention in toe walking at walking speed, we found that there were positive results and progress in increasing heel strike, flatfoot, swing force and ground impact as well as decreasing of stride length. Articles were found where they showed positive results of ES in spontaneous spastic paraparesis or even in adults with motor problems definitely proving the positive effect of the treatment - dealing with this, however as evidenced by our own research, there is definitely a need for further investigation of the specific method.[27,28] No similar articles were found of children with ITW that the application of electrical stimulation was applied.

Regarding the effectiveness of physical exercises, in a study that included 20 participants that had received inactive treatment with recommended stretching exercises showed significant improvement in peak ankle power, timing of ankle kinematics and kinetics in the gait cycle, internal plantar flexor moments, whereas knee extension increased in stance and passive ankle dorsiflexion decreased at follow-up (p=0.001).[14]

Future research must focus on conducting RCTs for noticeably better outcomes and concentrating on TW as the main problem to increase the clinical and scientific importance. It should definitely be further investigation in future research studies how electrotherapy can benefit toe-walking, and certainly other frequencies should be used and evaluated for their potential effectiveness. Additionally, studies administering Botox at different dosages, as well as how physical therapy techniques in combination with the above or as an independent treatment plan can benefit and improve cases of children with toe-walking should be conducted.

It is also crucial to discuss the systematic review's limitations. First, the limited number of participants in these research restricts the potential generalization of the results to the general population, and the relative range of the rating scales applied makes it impossible to draw safe assumptions. The long-term outcomes of the studies included in the systematic review are unknown, making it impossible to come to the necessary conclusions regarding the time frame of the effect of the treatment methods. Furthermore, in many researches, specialized questionnaires were used to record the parents' opinion of the frequency of toe walking, which is not so validated. It's worth mentioning that a meta -analysis is not feasible due to significant variability among the interventions that were performed and studied; therefore, there would be considerable heterogeneity in the results too.

## CONCLUSION

The effect of conservative treatment and physical therapy exercises on children with ITW and TW is beneficial. When conservative interventions such as botulinum toxin, AFOs and FOs, electrical stimulation therapy are combined with physical therapy exercises seemed to help children more. Future research in this sector is considered vital, with the goal of identifying the most proven therapeutic forms of conservative treatment with the goal of direct and focused intervention in these conditions and improving the daily lives of these individuals with the main objective of avoiding major, costly and health risky surgeries for children.

*Funding: No funding sources*
*Conflict of interest: None declared*
*Ethical approval: Not required*

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**Cite this article as:** Besios P, Kyriakatis GM, Besios T. Conservative therapy and physiotherapy in children with toe walking - a systematic review. Int J Clin Trials 2024;11(3):231-9.