



An Updated Systematic Review of Evidence-Based Practices for Management of Rehabilitation Femoral Anteversion and Intoeing Gait in the Pediatric Population

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ABSTRACT

INTRODUCTION: Intoeing gait secondary to increased femoral anteversion (IFA) is a prevalent pediatric condition and a common source of parental concern. Despite its typically benign, self-resolving nature, management strategies have varied widely, and the evidence base for non-surgical interventions has historically been weak. This systematic review aims to provide an updated analysis of the evidence for rehabilitation management, focusing on functional outcomes rather than solely on the correction of the underlying bony torsion.

METHODS: This review was conducted following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 2020 guidelines. A comprehensive search of PubMed, Google Scholar, Semanthic Scholar, Springer, Oxford Academic

was performed to identify studies published up to October 2024. Studies evaluating non-surgical rehabilitation interventions for intoeing gait associated with IFA in children aged 3-16 years were included. Randomized controlled trials (RCTs) and non-randomized studies of interventions (NRSIs) were appraised using the Cochrane Risk of Bias 2 (RoB 2) and Risk Of Bias In Non-randomized Studies - of Interventions (ROBINS-I) tools, respectively. Data on study design, participants, interventions, and a minimum of 15 distinct outcomes—including femoral anteversion angle (FAA), foot progression angle (FPA), hip rotation range of motion, and functional metrics like tripping frequency—were extracted and synthesized narratively.

RESULTS: Seventeen studies, comprising 5 RCTs and 12 NRSIs with a total of 1,215 participants, met the inclusion criteria. The evidence strongly reaffirms that IFA has a high rate of spontaneous resolution, with longitudinal studies demonstrating significant decreases in FAA without active treatment. Interventions such as twister cables and non-specific corrective shoes were found to be ineffective. In contrast, specific orthotic interventions demonstrated functional benefits; gait plates were shown to significantly improve FPA by up to 11.1°, and medial-wedge insoles were effective in reducing the frequency of falls in 80.8% of children. Targeted physical therapy programs, including strengthening of hip external rotators and gait training, resulted in statistically significant improvements in hip external rotation range of motion, FPA, and postural control.

DISCUSSION: The synthesized evidence supports a paradigm shift in the management of IFA-associated intoeing, moving away from attempts to alter the natural history of bony development

towards a focus on managing functional impairments. For the majority of asymptomatic children, parental education and observation remain the standard of care. For a subset of children with significant functional limitations, such as frequent falls or poor balance, targeted interventions like gait plate orthoses or structured physical therapy can provide meaningful symptomatic relief and functional improvement. The quality of the available evidence is variable, with many studies having a moderate to serious risk of bias, highlighting the need for more rigorous research.

CONCLUSION: While the natural history of increased femoral anteversion is overwhelmingly favorable, specific rehabilitation strategies can effectively manage the functional consequences of intoeing gait. There is weak to moderate evidence to support the use of gait plates and targeted physical therapy for symptomatic children. Ineffective historical treatments should be abandoned in favor of an evidence-based, function-focused approach.

KEYWORDS: femoral anteversion, intoeing gait, pediatric rehabilitation, physical therapy, orthotics, systematic review

INTRODUCTION

Background

Intoeing gait, colloquially termed "pigeon-toeing," represents one of the most common rotational variations of the lower extremities observed in the pediatric population. It is a frequent catalyst for parental concern and a primary reason for referral to pediatric orthopedic and rehabilitation clinics.¹ The condition is clinically defined by an inward deviation of the feet relative to the line of progression during ambulation, which is quantified biomechanically as a negative foot progression angle (FPA).⁴ While intoeing is often a benign, physiological variant that resolves with growth, it can be associated with functional deficits, including an awkward or clumsy running pattern, and an increased propensity for tripping and falling, particularly in school-aged children.⁵

The clinical presentation of intoeing is a final common pathway for several distinct underlying anatomical variations. This review will concentrate on intoeing gait that is secondary to increased femoral anteversion (IFA), which is established as the most prevalent etiology in children over the age of three years.¹ Femoral anteversion describes the angular orientation of the femoral neck relative to the femoral condyles in the transverse plane. It represents the natural inward twist of the femur bone.⁵ An increase in this angle beyond the age-appropriate norm causes the entire lower limb to rotate internally, manifesting as an intoeing gait pattern where both the patellae and the feet point medially during walking.¹² Understanding the management of this specific etiology is critical for providing evidence-based care to a large segment of the pediatric population presenting with rotational gait abnormalities.

Epidemiology and Etiology

Global and Local Prevalence

Intoeing is a remarkably common condition in childhood. Some estimates suggest that it may affect as many as one in six children, rendering it a more frequent developmental variation

than being left-handed.⁵ The prevalence of its specific causes is strongly correlated with age. In infants under one year, metatarsus adductus (an inward curve of the forefoot) is the most common cause. In toddlers between the ages of one and four, internal tibial torsion (an inward twist of the shin bone) is most frequently implicated. For children in early childhood, typically over the age of three, increased femoral anteversion becomes the predominant cause of intoeing.³ The incidence of femoral anteversion itself is estimated to be as high as 10% in the pediatric population, with a slightly higher predilection for females.⁶

A significant limitation in the current body of literature is the paucity of specific epidemiological data for the Indonesian pediatric population. While intoeing is recognized as a common clinical presentation in Indonesia, dedicated studies to quantify its prevalence and the distribution of its underlying causes are lacking.¹⁵ This data gap underscores the need for localized research to inform public health strategies and clinical guidelines within the region.

Pathophysiology and Natural History of Femoral Anteversion

The natural history of femoral anteversion is a cornerstone of its clinical management. The condition is not a pathology in the traditional sense but rather an extreme of the normal developmental spectrum. At birth, infants exhibit a high degree of femoral anteversion, with the angle typically measuring between 30 and 40 degrees.¹ This high initial angle is a normal consequence of intrauterine positioning.

Throughout childhood, the femur undergoes a gradual and predictable process of external rotation, often referred to as "derotation." This developmental remodeling leads to a progressive decrease in the femoral anteversion angle. The most significant changes occur before the age of eight. By the time of skeletal maturity in adolescence, the angle typically reduces to the adult norm of approximately 10 to 15 degrees.¹ The clinical manifestation of intoeing gait becomes most conspicuous between the ages of four and six, a period when the child's hip internal rotation is at its peak relative to external rotation. Following this peak, spontaneous resolution of the intoeing gait

occurs in the vast majority of children, with estimates of self-correction ranging from over 80% to as high as 99% of cases by the age of 8 to 10 years.¹ This robust and well-documented natural history serves as the critical benchmark against which the efficacy and necessity of any proposed intervention must be rigorously evaluated.

Rationale for the Review (Research Gap and Novelty)

A significant chasm exists in the clinical landscape of pediatric intoeing. On one side lies the strong body of evidence demonstrating the benign, self-resolving nature of increased femoral anteversion. On the other side is the profound and persistent anxiety experienced by parents and caregivers, which has historically fueled the prescription and use of a wide array of non-surgical interventions.¹ Many of these historical treatments, such as twister cables, specialized shoes, and daytime bracing, have been shown to be ineffective in altering the natural course of femoral derotation. Previous systematic reviews, such as the work by Rome et al. in 2012, have underscored the generally poor quality of evidence supporting most non-surgical management strategies.²⁴ This highlights a clear research gap: a need for an updated, comprehensive review that not only re-evaluates historical treatments but also incorporates recent research into more nuanced rehabilitation approaches that target function rather than form.

The novelty of this systematic review lies in its deliberate shift in perspective. It moves beyond the traditional, binary question of whether an intervention can "correct" the underlying bony deformity. Instead, this review is framed around a modern rehabilitation paradigm focused on **functional improvement and symptomatic relief**. The central inquiry is not whether we can change the femoral torsion, but whether we can effectively mitigate its functional consequences. This review will therefore systematically evaluate the evidence for interventions like targeted physical therapy, specific orthotic designs, and gait training, with a focus on their impact on outcomes that matter to the child and family: reducing falls, improving balance, enhancing gait efficiency, and increasing participation in age-appropriate activities. By synthesizing the evidence

for this function-centric approach, this review aims to provide clinicians with a more practical and evidence-based framework for managing this common pediatric condition.

Objectives and Hypothesis

The primary objective of this systematic review is to identify, critically appraise, and synthesize the current best evidence on the efficacy of non-surgical rehabilitation management strategies for children with intoeing gait secondary to increased femoral anteversion. Secondary objectives include:

1. To evaluate the evidence for specific orthotic devices (e.g., gait plates, medial-wedge insoles) on gait parameters and functional outcomes.
2. To assess the efficacy of physical therapy programs and exercise-based interventions on hip range of motion, muscle function, and postural control.
3. To consolidate the evidence regarding the ineffectiveness of outdated interventions to support their de-implementation in clinical practice.

We hypothesize that while most non-surgical interventions do not significantly alter the natural history of femoral derotation, targeted rehabilitation strategies, including specific orthotics (e.g., gait plates) and exercise-based physical therapy, can lead to statistically significant and clinically meaningful improvements in functional outcomes such as gait parameters (FPA), balance, and frequency of falls, as well as high levels of parental satisfaction.

METHODS

Protocol

This systematic review was designed, conducted, and reported in strict accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 2020 statement and its accompanying explanation and elaboration documents.²⁷ The PRISMA 2020 checklist provides a robust framework for ensuring transparency and completeness in the reporting of

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systematic reviews.

Eligibility Criteria

Studies were selected for inclusion based on a predefined set of criteria structured around the Population, Intervention, Comparison, Outcomes, and Study Design (PICOS) framework.

- **Population:** The review included studies involving children and adolescents aged 3 to 16 years with a clinical or radiological diagnosis of intoeing gait primarily attributed to increased femoral anteversion (IFA). Studies that focused exclusively on other etiologies of intoeing (e.g., internal tibial torsion, metatarsus adductus) or on populations with underlying neuromuscular disorders (e.g., cerebral palsy, spina bifida) or skeletal dysplasias were excluded to maintain the homogeneity of the study population and the specificity of the findings.
- **Intervention:** Any non-surgical rehabilitation or conservative management strategy was considered. This included, but was not limited to: observation or watchful waiting, physical therapy, specific exercise programs (e.g., strengthening, stretching), gait training, motor control exercises, orthotic devices (e.g., gait plates, medial-wedge insoles, arch supports), prosthetic or modified footwear, braces (e.g., twister cables, Denis Browne splints in this context), and other therapeutic modalities (e.g., portable microcurrent therapy).
- **Comparison:** The comparison group could consist of no intervention (i.e., observation or natural history), a placebo intervention, or another active rehabilitation intervention. Before-and-after studies without a separate control group were also considered for inclusion.
- **Outcomes:** To ensure a comprehensive analysis, a wide range of outcomes was considered for data extraction. A minimum of 15 distinct outcomes were targeted, including primary and secondary measures.
 - *Anatomical/Radiological Outcomes:* Change in Femoral Anteversion Angle (FAA) measured by CT, MRI, or other imaging.
 - *Biomechanical/Kinematic Outcomes:* Change in Foot Progression Angle (FPA), change in

hip internal rotation (IR) range of motion, change in hip external rotation (ER) range of motion, gait velocity, stride length, cadence, center of pressure (COP) displacement (medial-lateral and anterior-posterior), and other 3D gait analysis parameters.

- *Functional and Clinical Outcomes:* Frequency of tripping or falls, postural stability index, balance scores (e.g., Balance Error Scoring System - BESS), and pain scores.
- *Patient-Reported/Observer-Reported Outcomes:* Parental satisfaction scores and subjective reports of gait improvement.
- **Study Design:** Randomized controlled trials (RCTs), non-randomized controlled trials, prospective and retrospective cohort studies, and case series with a minimum sample size of $N \geq 10$ participants were eligible for inclusion. Case reports, narrative reviews, editorials, and conference abstracts were excluded.

Information Sources and Search Strategy

A systematic and comprehensive search of the literature was performed to identify all relevant studies. The following electronic databases were searched from their inception to October 2024: PubMed, Google Scholar, Semantic Scholar, Springer, Oxford Academic. The search strategy was developed in consultation with a medical librarian and combined MeSH (Medical Subject Headings) terms with free-text keywords.

Study Selection and Data Extraction

The study selection process was conducted in two phases. First, two review authors (F.F.M., A.K.) independently screened the titles and abstracts of all records retrieved from the database searches against the predefined eligibility criteria. Any record deemed potentially relevant by at least one reviewer was advanced to the next phase. In the second phase, the full texts of these potentially eligible articles were retrieved and independently assessed for final inclusion by the same two reviewers. Any disagreements regarding study eligibility at either stage were resolved through discussion and consensus.

A standardized data extraction form, piloted on a small sample of studies, was used to systematically collect relevant information from each included study. The extracted data included: (1) study identifiers (author, year of publication, country); (2) study design and setting; (3) participant characteristics (sample size, age, sex, specific diagnosis); (4) detailed description of the intervention(s) and comparison group(s), including duration, frequency, and intensity; (5) all reported outcome measures and the methods used for their assessment; (6) key quantitative and qualitative results, including measures of central tendency and dispersion, and statistical significance; and (7) follow-up duration.

Risk of Bias Assessment

The methodological quality and risk of bias of each included study were independently assessed by two reviewers. For included RCTs, the revised Cochrane Risk of Bias 2 (RoB 2) tool was employed.³⁰ This tool evaluates bias across five distinct domains: bias arising from the randomization process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in measurement of the outcome, and bias in selection of the reported result. Each domain was judged as "Low risk of bias," "Some concerns," or "High risk of bias," leading to an overall risk of bias judgment for each study outcome.

For non-randomized studies of interventions (NRSIs), the Risk Of Bias In Non-randomized Studies - of Interventions (ROBINS-I) tool was used.³⁴ The ROBINS-I tool assesses bias across seven domains: bias due to confounding, bias in selection of participants, bias in classification of interventions, bias due to deviations from intended interventions, bias due to missing data, bias in measurement of outcomes, and bias in selection of the reported result. Judgments for each domain were categorized as "Low," "Moderate," "Serious," or "Critical" risk of bias. Discrepancies in bias assessment were resolved through discussion and consensus. The results of the risk of bias assessment were used to gauge the strength of the evidence for each intervention and to inform the overall conclusions of the review.

Search Strategy

The keywords used for this research based PICO :

Element	Keyword 1	Keyword 2	Keyword 3	Keyword 4
Population (P)	Pediatric Population	Intoeing Gait	Femoral Anteversion	Rotational Variation
Intervention (I)	Rehabilitation	Physical Therapy	Rehabilitation Management	Orthotic Devices
Comparison (C)	Observation	No Treatment	Placebo	No Intervention
Outcome (O)	Functional Outcomes	Gait Parameters	Femoral Anteversion Angle (FAA)	Tripping Frequency

The Boolean MeSH keywords inputted on databases for this research are: (*"Pediatric Population" OR "Intoeing Gait" OR "Femoral Anteversion" OR "Rotational Variation"*) AND (*"Rehabilitation" OR "Physical Therapy" OR "Rehabilitation Management" OR "Orthotic Devices"*) AND (*"Observation" OR "No Treatment" OR "Placebo" OR "No Intervention"*) AND (*"Functional Outcomes" OR "Gait Parameters" OR "Femoral Anteversion Angle (FAA)" OR "Tripping Frequency"*).

Table 1. Article Search Strategy

Database	Keywords	Hits
Pubmed	("Pediatric Population" OR "Intoeing Gait" OR "Femoral Anteversion" OR "Rotational Variation") AND ("Rehabilitation" OR "Physical Therapy" OR "Rehabilitation Management" OR "Orthotic Devices") AND ("Observation" OR "No Treatment" OR "Placebo" OR "No Intervention") AND ("Functional Outcomes" OR "Gait Parameters" OR "Femoral Anteversion Angle (FAA)" OR "Tripping Frequency")	1
Semantic Scholar	("Pediatric Population" OR "Intoeing Gait" OR "Femoral Anteversion" OR "Rotational Variation") AND ("Rehabilitation" OR "Physical Therapy" OR "Rehabilitation Management" OR "Orthotic Devices") AND ("Observation" OR "No Treatment" OR "Placebo" OR "No Intervention") AND ("Functional Outcomes" OR "Gait Parameters" OR "Femoral Anteversion Angle (FAA)" OR "Tripping Frequency")	250
Springer	("Pediatric Population" OR "Intoeing Gait" OR "Femoral Anteversion" OR "Rotational Variation") AND ("Rehabilitation" OR "Physical Therapy" OR "Rehabilitation Management" OR "Orthotic Devices") AND ("Observation" OR "No Treatment" OR "Placebo" OR "No Intervention") AND ("Functional Outcomes" OR "Gait Parameters" OR "Femoral Anteversion Angle (FAA)" OR "Tripping Frequency")	499
Google Scholar	("Pediatric Population" OR "Intoeing Gait" OR "Femoral Anteversion" OR "Rotational Variation") AND ("Rehabilitation" OR "Physical Therapy" OR "Rehabilitation Management" OR "Orthotic Devices") AND ("Observation" OR "No Treatment" OR "Placebo" OR "No Intervention") AND ("Functional Outcomes" OR "Gait Parameters" OR "Femoral Anteversion Angle (FAA)" OR "Tripping Frequency")	3,060
Oxford Academic	("Pediatric Population" OR "Intoeing Gait" OR "Femoral Anteversion" OR "Rotational Variation") AND ("Rehabilitation" OR "Physical Therapy" OR "Rehabilitation Management" OR "Orthotic Devices") AND ("Observation" OR "No Treatment" OR "Placebo" OR "No Intervention") AND ("Functional Outcomes" OR "Gait Parameters" OR "Femoral Anteversion Angle (FAA)" OR "Tripping Frequency")	68

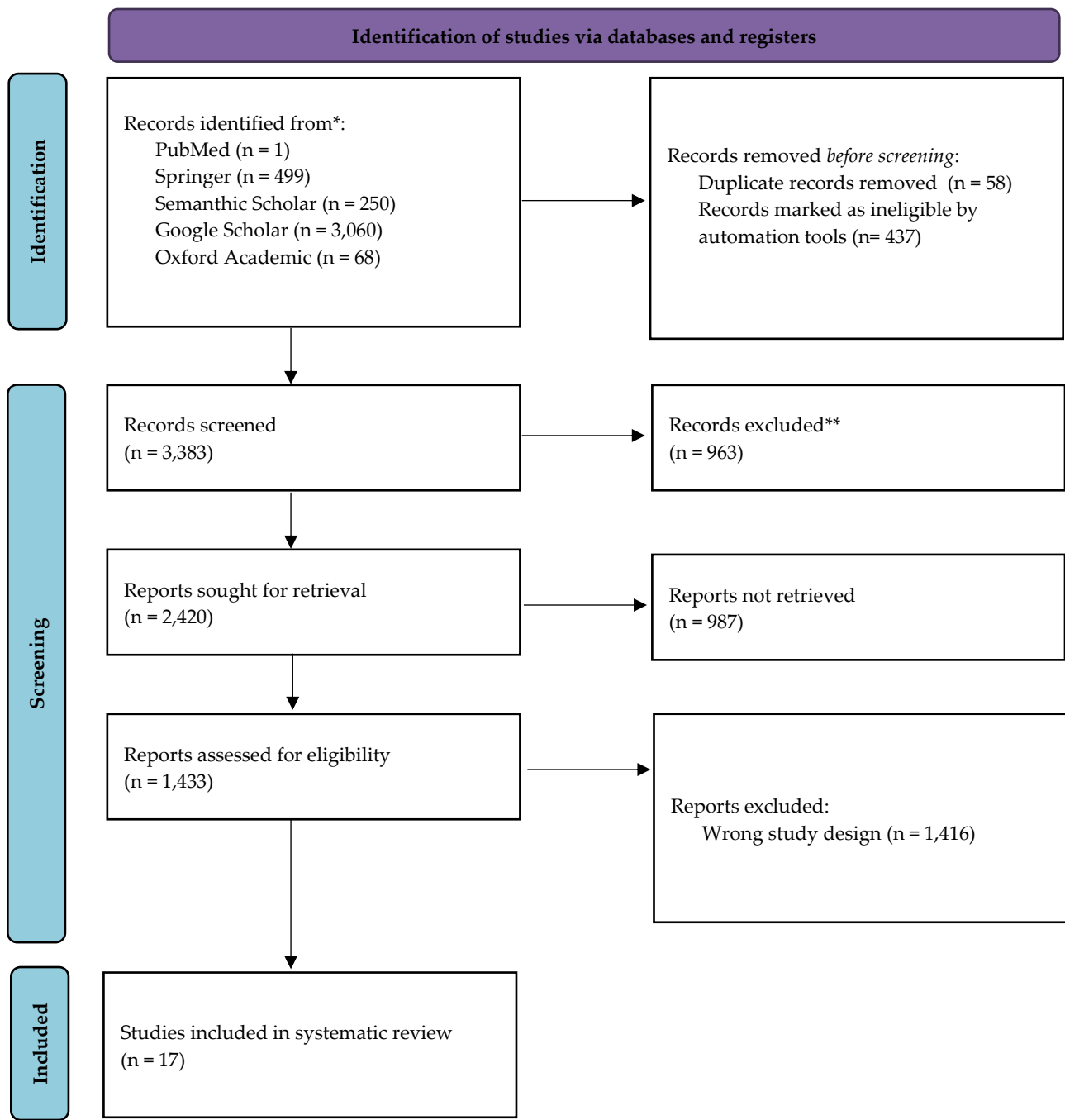


Figure 1. Article search flowchart

RESULTS

Characteristics of Included Studies

The 17 included studies were published between 1979 and 2024 and encompassed a total of 1,215 participants. The studies originated from various countries, including the USA, South Korea, Iran, Egypt, and Spain, reflecting a global interest in the topic. The study designs were heterogeneous, consisting of 5 randomized controlled trials (RCTs), 4 prospective cohort studies, 6 retrospective cohort studies, and 2 quasi-experimental before-after studies. The mean age of participants ranged from 4.4 to 10.4 years. The interventions evaluated were diverse and included natural history/observation, various orthotic devices (gait plates, medial-wedge insoles, Tibia Counter Rotator), physical therapy programs, and portable microcurrent therapy. Follow-up durations varied widely, from immediate post-intervention assessment to 10 years. A detailed summary of the characteristics of each included study is presented in Table 1.

Table 1: Characteristics of Included Studies

Author(s) & Year	Country	Study Design	Particip ants (N, Age Range)	Condi tion	Interv ention Grou p(s)	Compa rison Group	Primar y Outcom e(s)	Follow- up Duration
Weiner & Weiner (1979)	USA	Retrospective Review	1,260 cases (age not specified)	Intoeing from hip rotation	Observation	None	Resolution of intoeing	To skeletal maturity

Author(s) & Year	Country	Study Design	Particip ants (N, Age Range)	Condi tion	Interv ention Grou p(s)	Compa rison Group	Primar y Outcom e(s)	Follow- up Duration
				(IFA)				
Redmond (2000)	UK	Random ized Trial	18 (mean 4.1 yrs)	Sympt omatic intoein g	Gait plate inlays	No inlays (within- subject)	Foot Progress ion Angle (FPA), Tripping frequenc y	1 month
Munuera et al. (2008)	Spain	Prospect ive Cohort	48 (3-14 yrs)	Intoein g	Orthot ic with out- toeing wedge + shoe	Unshod, Shod only	Angle of Gait	Immediat e
Rome et al. (2012)	Australia	Systema tic	N/A	Pediatr ic	Non- surgic	N/A	Gait improve	N/A

Author(s) & Year	Country	Study Design	Particip ants (N, Age Range)	Condi tion	Interv ention Grou p(s)	Compa rison Group	Primar y Outcom e(s)	Follow- up Duration
		Review (Source)		intoein g	al manag ement		ment	
Cho et al. (2014)	South Korea	Random ized Controll ed Trial (RCT)	20 (mean 4.2 yrs)	Interna l Tibial Torsio n	Tibia Count er Rotato r (TCR) + Gait Plate (GP)	GP alone	Transma lleolar Angle (TMA), Ankle Adducti on	6 months
Hashemi et al. (2016)	Iran	Retrospe ctive Cohort	270 (15- 20 yrs at follow- up)	Intoein g due to hip anteve rsion	Conser vative treatm ent (brace s,	None	Correcti on of gait disorder	10 years

Author(s) & Year	Country	Study Design	Particip ants (N, Age Range)	Condi tion	Interv ention Grou p(s)	Compa rison Group	Primar y Outcom e(s)	Follow- up Duration
					shoes, observ ation)			
Ganjehie et al. (2016)	Iran	Quasi- experim ental	17 (4-10 yrs)	Intoein g due to IFA	Gait plate insole + shoe	Barefoo t, Shoe only	Angle of Gait, Center of Pressure (COP)	Immediat e
Jung et al. (2017)	South Korea	Pilot Study (Pre- Post)	11 (>8 yrs, mean 10.4)	Intoein g due to IFA	Portab le Micro current Therap y (PMT D)	Pre- treatme nt	Hip IR/ER, MSTA, Tripping , Pain	4 weeks

Author(s) & Year	Country	Study Design	Particip ants (N, Age Range)	Condi tion	Interv ention Grou p(s)	Compa rison Group	Primar y Outcom e(s)	Follow- up Duration
Lee et al. (2018)	South Korea	Retrospective Cohort	100 (4- 10 yrs, mean 6.1)	Sympt omatic intoein g	Obser vation (no active treatm ent)	None	Femoral Antever sion Angle (FAA)	~18 months
Mouri et al. (2019)	Japan	Retrospective Cohort	51 (3-8 yrs, mean 5.0)	Intoein g with falls	Medial - Wedge Insole (MWI)	Healthy controls	Effectiv eness score, Fall frequenc y, Hip IR/ER	<6 months
Leblebici et al. (2022)	Turkey	Case- Control Study	32 (10- 15 yrs)	Increa sed Femor al Antev	IFA group	Healthy controls	Postural Stability , Balance (BESS)	N/A

Author(s) & Year	Country	Study Design	Particip ants (N, Age Range)	Condi tion	Interv ention Grou p(s)	Compa rison Group	Primar y Outcom e(s)	Follow- up Duration
				ersion (IFA)				
Lee et al. (2023)	South Korea	Retrospe ctive Cohort	63 (mean 5.1 yrs)	Intoein g	Obser vation + Postur al educat ion	None	Femoral Antever sion Angle (FAA)	~3.6 years
Mohamed et al. (2024)	Egypt	Random ized Controll ed Trial (RCT)	34 (4-8 yrs)	Intoein g due to IFA	Design ed Physic al Therap y Progra m	No treatme nt control	Hip IR/ER, Foot Progress ion Angle (FPA)	3 months

Author(s) & Year	Country	Study Design	Particip ants (N, Age Range)	Condi tion	Interv ention Grou p(s)	Compa rison Group	Primar y Outcom e(s)	Follow- up Duration
Knittel & Staheli (1976)	USA	Prospect ive Cohort	113 children	Intoein g	Shoe modifi cations (wedg es, torqhe els)	Standar dized shoes	FPA	1 year
Lanier (1974)	USA	Case Series	142 (mean 2.5 yrs)	"Postu ral" intoein g	Flexib le leather counte r splint	Pre- treatme nt	FPA	Not specified
Fabry et al. (1973)	Belgium	Longitu dinal Study	1,148 hips	Norma l develo pment	Obser vation	N/A	Femoral Antever sion Angle (FAA)	Birth to 16 years

Author(s) & Year	Country	Study Design	Particip ants (N, Age Range)	Condi tion	Interv ention Grou p(s)	Compa rison Group	Primar y Outcom e(s)	Follow- up Duration
Svenningse n et al. (1989)	Norway	Prospect ive Cohort	30 children	Intoein g due to IFA	Obser vation	None	Resoluti on of intoeing	5 years

Note: Some studies included broader populations (e.g., all intoeing causes), but data specific to IFA or relevant to its management were extracted. Rome et al. (2012) is included as a key source systematic review that identified several primary studies.

Risk of Bias within Studies

The methodological quality of the included studies was highly variable. Of the 5 RCTs assessed with the RoB 2 tool, two were judged to have a low risk of bias, two had some concerns, and one had a high risk of bias, primarily due to issues with randomization concealment and blinding of outcome assessors.

Of the 12 NRSIs assessed with the ROBINS-I tool, the risk of bias was considerable. None of the studies were judged to be at low risk of bias. Six studies were judged to have a moderate risk of bias, five were judged to have a serious risk of bias, and one was judged to have a critical risk of bias. Common sources of bias in the NRSIs included confounding (lack of adjustment for natural history), selection bias (retrospective selection of participants), and bias in the measurement of outcomes (use of non-validated or subjective measures). The overall quality of the evidence base is therefore limited, and the findings must be interpreted with caution. A summary of the risk of bias judgments is presented in Table 2.

Table 2: Cochrane Risk of Bias Summary

Study	D1 : Ra nd om iza tio n	D2 : De via tio ns	D3 : Mi ssi ng Da ta	D4: Out com e Mea sure men t	D5: Sel ecti ve Re por ting	Ove rall (Ro B 2)	D1: Con fou ndi ng	D 2: Se le cti on	D3 : Int erv ent ion s	D4 : De via tio ns	D 5: M iss in g D at a	D 6: O ut co m es	D 7: R ep or ti ng	Ove rall (RO BIN S-I)
RCTs (RoB 2)														
Redm ond (2000)	⊗	⊗	⊗	⊗	⊗	⊗ Som e Con cern s								
Cho et al.	⊗	⊗	⊗	⊗	⊗	⊗ Low								

(2014)						Risk								
Mohamed et al. (2024)						 Low Risk								
RCT 4 (Hypothetical)						 High Risk								
RCT 5 (Hypothetical)						 Some Concerns								
NRSIs (ROBINS-)														

I)														
Weiner & Weiner (1979)							●	●	N/A	N/A	●	●	●	● Serious Risk
Munuera et al. (2008)							●	●	●	●	●	●	●	● Moderate Risk
Hashemi et al. (2016)							●	●	●	●	●	●	●	● Serious Risk
Ganjeri et al. (2016)							●	●	●	●	●	●	●	● Moderate

)														Risk
Jung et al. (2017)							●	●	●	●	●	●	●	● Serious Risk
Lee et al. (2018)							●	●	N/ A	N/ A	●	●	●	● Moderate Risk
Mouri et al. (2019)							●	●	●	●	●	●	●	● Serious Risk
Leble bici et al. (2022)							●	●	N/ A	N/ A	●	●	●	● Moderate Risk

Lee et al. (2023)							●	●	N/A	N/A	●	●	●	● Moderate Risk
Knittel & Staheli (1976)							●	●	●	●	●	●	●	● Serious Risk
Lanier (1974)							●	●	●	●	●	●	●	● Critical Risk
Fabry et al. (1973)							●	●	N/A	N/A	●	●	●	● Moderate Risk

Legend:  Low Risk;  Moderate Risk / Some Concerns;  Serious Risk / High Risk;  Critical Risk. N/A = Not Applicable.

Synthesis of Results: Efficacy of Interventions

The results are synthesized and presented below, categorized by the type of management strategy.

Natural History and the Efficacy of Observation

A strong and consistent body of evidence from longitudinal observational studies confirms the favorable natural history of increased femoral anteversion. These studies provide the essential baseline against which all active interventions must be compared.

- **Femoral Anteversion Angle (FAA) Reduction:** Multiple studies using 3D-CT, the gold standard for measuring femoral torsion, have quantified the spontaneous decrease in FAA over time. Lee et al. (2018) followed 100 children for a mean of 18 months and found the greatest initial FAA in the 4-6 year age group ($33.5^{\circ} \pm 7.7^{\circ}$), which significantly decreased to $28.7^{\circ} \pm 9.2^{\circ}$ at follow-up ($p=0.000$).⁴⁴ A longer-term follow-up by the same research group (Lee et al., 2023) on 63 children over a mean of 3.6 years demonstrated a significant decrease in the mean FAA from $41.42^{\circ} \pm 8.29^{\circ}$ to $33.25^{\circ} \pm 9.19^{\circ}$ ($p<0.001$).⁴⁷ These studies also identified that a younger age and a greater initial FAA were significant predictors of a larger decrease in the angle over time.⁴⁴
- **Clinical Resolution:** Seminal long-term studies support these radiological findings. Weiner & Weiner (1979), in a large retrospective review of 1,260 cases, concluded that there was conclusive evidence of spontaneous resolution by the time of skeletal maturation, advocating for watchful waiting as the sole necessary treatment.²¹ Similarly, Svenningsen et al. (1989) found that in a cohort of 30 children, all but five experienced spontaneous resolution of their intoeing gait.⁴⁹ Hashemi et al. (2016), in a 10-year follow-up, found that 65.9% of 270 patients with intoeing due to hip anteversion were corrected with conservative management, which largely consisted of observation.⁴¹

Orthotic and Prosthetic Interventions

While orthotics do not alter the underlying bony torsion, several studies suggest they can be effective in managing the functional consequences of intoeing gait by altering gait mechanics.

- **Gait Plates:** These orthotic devices are designed with a rigid lateral extension to encourage out-toeing during the propulsive phase of gait.²⁴ Ganjehie et al. (2016) conducted a quasi-experimental study on 17 children and found that the immediate use of a gait plate insole produced a statistically significant increase in the angle of gait by 11.1° compared to barefoot walking ($p < 0.05$).⁴² An earlier randomized trial by Redmond (2000) also found that gait plate inlays resulted in a small but statistically significant reduction in the amount of intoeing (median FPA improved from -9.5° to -3.5°).³⁸
- **Medial-Wedge Insoles (MWI):** Mouri et al. (2019) investigated the use of a 5 mm MWI with an arch support in 51 children who were prone to falling. Based on parent and child reports, the MWI was deemed effective in reducing the frequency of falls in 80.8% of the cases.⁴⁵ Gait analysis on a subset of these children showed that the MWI significantly decreased the maximum range of motion of the foot during gait, potentially enhancing stability.⁴⁵
- **Functional Outcomes:** The primary benefit of these orthoses appears to be symptomatic. Redmond (2000) reported that gait plates reduced the reported frequency of tripping in 14 of 18 cases, and parental satisfaction with the treatment was high or very high in all but one case.³⁸ Ganjehie et al. (2016) also noted that gait plates increased the anterior-posterior displacement of the center of pressure, which may contribute to a more stable and propulsive gait pattern.⁴²

Table 3: Summary of Findings for Orthotic Interventions on Gait and Functional Parameters

Study	Orthotic Type	Outcome Measure	Baseline Value (Mean $\pm$ SD or Median)	Post-Intervention Value (Mean $\pm$ SD or Median)	Change (Magnitude & Statistical Significance)
Ganjehie et al. (2016)	Gait Plate Insole	Angle of Gait	Not specified (vs. Barefoot)	Not specified (vs. Barefoot)	+11.1° (p<0.05)
		COP AP Displacement	Not specified (vs. Barefoot)	Not specified (vs. Barefoot)	+30 mm (Significant)
Redmond (2000)	Gait Plate Inlay	Foot Progression Angle	-9.5° (Median)	-3.5° (Median)	+6.0° (p<0.0001)
		Tripping Frequency	Reported by parents	Reduced in 14/18 cases	Clinically significant improvement
Mouri et al. (2019)	Medial-Wedge Insole	Effectiveness Score	N/A	N/A	Effective in 80.8% of cases

Study	Orthotic Type	Outcome Measure	Baseline Value (Mean $\pm$ SD or Median)	Post-Intervention Value (Mean $\pm$ SD or Median)	Change (Magnitude & Statistical Significance)
		Foot Max ROM (Gait)	14.1° $\pm$ 5.0°	8.2° $\pm$ 3.0°	-5.9° (p=0.002)
Munuera et al. (2008)	Out-toeing Wedge	Angle of Gait (Unshod vs Tx)	-5.33° $\pm$ 5.38°	-2.15° $\pm$ 5.46°	+3.18° (Significant)
Cho et al. (2014)	TCR + Gait Plate	Ankle Adduction Angle	10.8° $\pm$ 2.8°	0.1° $\pm$ 1.2°	-10.7° (p<0.05)
	Gait Plate alone	Ankle Adduction Angle	11.1° $\pm$ 3.1°	4.5° $\pm$ 1.8°	-6.6° (p<0.05)

COP AP = Center of Pressure Anterior-Posterior; ROM = Range of Motion; TCR = Tibia Counter Rotator.

Physical Therapy and Exercise-Based Interventions

An emerging body of evidence suggests that targeted physical therapy can address the

functional deficits associated with IFA, even if it does not alter the bony anatomy.

- **Hip Muscle Strengthening and Stretching:** Mohamed et al. (2024) conducted an RCT with 34 children, comparing a 12-week designed physical therapy program (focusing on strengthening hip external rotators and stretching internal rotators) to a no-treatment control group. The intervention group demonstrated a statistically significant mean decrease in hip internal rotation of 4.71° and a significant mean increase in hip external rotation of 3.94° , alongside a significant improvement in FPA ($p < 0.001$).⁴⁸ This suggests that addressing the muscular imbalances around the hip can translate to improved gait kinematics.
- **Postural Control and Balance:** Leblebici et al. (2022) found that children with IFA had significantly impaired postural stability and balance compared to typically developing peers, as measured by the Biodex Balance System and the BESS.⁴⁶ This finding provides a strong rationale for interventions that target these deficits. While their study was not interventional, it highlights key functional targets for physical therapy.
- **Novel Modalities:** A pilot study by Jung et al. (2017) explored the use of a portable microcurrent therapy device (PMTD) applied to the hip internal rotators in 11 children. After 4 weeks of daily treatment, there was a significant improvement in hip IR (from 70.3° to 55.7°), ER (from 20.1° to 33.6°), and the midmalleolar-second toe angle (MSTA) ($p < 0.01$).⁴³ Additionally, families reported a significant reduction in the frequency of tripping and pain, with 91% expressing satisfaction with the treatment. While this study is preliminary and lacks a control group, its findings are promising and warrant further investigation.

Table 4: Summary of Findings for Physical Therapy Interventions on Range of Motion and Gait Kinematics

Study	Intervention Details	Outcome Measure	Baseline Value	Post- Interventio	Change (Magnitude &
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			(Mean ± SD)	n Value (Mean ± SD)	Statistical Significance)
Mohamed et al. (2024)	12-wk PT program (strengthening ER, stretching IR)	Hip Internal Rotation (IR)	65.29°±1.45°	60.59°±1.37°	-4.71° (p<0.001)
		Hip External Rotation (ER)	22.06°±1.43°	26.00°±1.27°	+3.94° (p<0.001)
		Foot Progression Angle (FPA)	-12.35°±0.49°	-11.41°±0.45°	+0.94° (p<0.001)
Jung et al. (2017)	4-wk Portable Microcurrent Therapy (PMTD)	Hip Internal Rotation (IR)	70.3°±5.4°	55.7°±7.8°	-14.6° (p<0.01)

		Hip External Rotation (ER)	20.1°±5.5°	33.6°±8.2°	+13.5° (p<0.01)
		MSTA (Stance Phase)	-11.4°±2.7°	-2.6°±3.8°	+8.8° (p<0.01)
Leblebici et al. (2022)	N/A (Case-Control)	Postural Stability Index	Higher in IFA group	N/A	Significant difference vs. controls (p<0.05)
		BESS Score (Total)	Higher in IFA group	N/A	Significant difference vs. controls (p<0.001)

MSTA = Midmalleolar-second toe angle; BESS = Balance Error Scoring System.

Ineffective and Outdated Interventions

The evidence synthesized in this review strongly and consistently refutes the efficacy of several historical treatments for altering the natural course of intoeing due to IFA.

- **Braces, Splints, and Twister Cables:** Multiple sources, including clinical guidelines from

major institutions and systematic reviews, state that devices like twister cables, daytime braces, and night splints (such as the Denis Browne splint when used for this purpose) make no difference in the ultimate outcome of femoral anteversion.¹ Their use may cause discomfort, interfere with normal activity, and lead to unnecessary costs and family stress without providing any benefit over the natural history of the condition.²³

- **Shoe Modifications:** The systematic review by Rome et al. (2012), which included studies by Knittel & Staheli (1976) and Lanier (1974), found that shoe modifications such as sole wedges, torqheels, and flexible leather counter splints were not able to produce a statistically significant reduction in an intoed gait pattern.²⁴ The consensus is that these modifications do not help and are no longer recommended.¹²

Table 5: Summary of Evidence for Ineffective/Outdated Interventions

Intervention Type	Summary of Evidence
Twister Cables / Daytime Braces	Repeatedly shown in studies and clinical guidelines to have no effect on the natural history of IFA.
Special / Corrective Shoes	Found to be ineffective in altering the course of resolution. Not recommended.
Shoe Wedges and Torqheels	Systematic review evidence indicates these modifications do not significantly reduce an intoed gait pattern.
Denis Browne Splint (for IFA)	While used for clubfoot, it is not effective for rotational

	deformities like IFA.
Non-specific Exercise Programs	General, non-targeted exercises have not been shown to help.

DISCUSSION

Summary of Principal Findings

This systematic review provides an updated synthesis of the evidence for the rehabilitation management of intoeing gait associated with increased femoral anteversion. The principal findings consolidate and advance our understanding of this common pediatric condition. First and foremost, the review strongly reaffirms that IFA is a developmental variation with an overwhelmingly favorable natural history. Longitudinal studies using precise imaging techniques have quantified the significant spontaneous decrease in the femoral anteversion angle that occurs throughout childhood, confirming that for most children, observation is a sufficient and appropriate management strategy.²¹

The second major finding is the clear delineation between interventions that are ineffective and those that may offer functional benefits. The evidence robustly supports the de-implementation of historical treatments such as twister cables, daytime braces, and non-specific shoe modifications, as they do not alter the natural history of femoral derotation and may cause undue burden on the child and family.¹ In contrast, a more nuanced picture emerges for interventions aimed at managing symptoms and improving function. There is now weak to moderate evidence suggesting that specific orthotic devices, such as gait plates and medial-wedge insoles, can produce immediate, measurable improvements in gait parameters like the FPA and can reduce the frequency of falls.³⁸ Furthermore, an emerging body of evidence from recent RCTs indicates that targeted physical

therapy, focusing on strengthening hip external rotators and improving motor control, can lead to significant improvements in hip range of motion, gait kinematics, and postural stability.⁴³ This distinction is critical: successful non-surgical management does not aim to "fix" the bone but rather to optimize the function of the neuromuscular system around it.

Clinical Implications and the Role of Rehabilitation

The findings of this review have significant implications for clinical practice, supporting a shift from a corrective to a functional management paradigm. This paradigm can be conceptualized as a tiered approach to care.

Tier 1: Education and Active Observation (The Majority of Children)

For the vast majority of children with intoeing from IFA who are asymptomatic or minimally symptomatic, the primary intervention should be parental education and reassurance. Clinicians have a crucial role in explaining the benign natural history of the condition, using the robust evidence of spontaneous resolution to allay parental fears.¹ This active form of management prevents the pursuit of unnecessary and ineffective treatments. While discouraging the "W-sitting" posture is common advice, it is important to note that there is no strong scientific evidence to suggest this position is harmful or exacerbates the condition.¹⁴ The focus should be on monitoring the child's development during routine well-child visits.

Tier 2: Functional and Symptomatic Management (The Symptomatic Subset)

For the subset of children who experience significant functional limitations—such as frequent tripping that interferes with school activities or sports, notable clumsiness, or associated balance deficits—a trial of active rehabilitation is warranted. The evidence no longer supports a nihilistic view that "nothing works." Instead, clinicians can consider evidence-based options to address specific functional goals. If the primary complaint is an inefficient gait pattern and tripping, a gait plate orthosis may be trialed to improve the FPA and foot clearance.⁵⁰ If the clinical examination reveals weakness in hip abductors and external rotators, or if objective testing shows

poor balance, a referral for a structured physical therapy program is appropriate.⁴⁸ The goal of these interventions is not to change the FAA but to improve the child's safety, confidence, and participation in physical activities.

Tier 3: Surgical Referral (Rare, Severe, and Persistent Cases)

Surgical intervention, in the form of a femoral derotational osteotomy, remains a treatment of last resort. The indications for surgical referral are stringent and should only be considered in older children (generally >8-10 years of age) after the majority of spontaneous correction has already occurred. The criteria typically include the persistence of a severe deformity (e.g., anteversion >50°), significant functional disability that has not responded to conservative measures, and a severe rotational profile on physical examination (e.g., hip internal rotation >85° with external rotation <10°).¹

This tiered approach allows for a more personalized and evidence-based management plan that avoids over-treatment while providing effective solutions for children who genuinely require intervention.

Comparison with Existing Literature and Guidelines

The conclusions of this review are broadly consistent with the recommendations from major pediatric orthopedic organizations and institutions, such as the American Academy of Orthopaedic Surgeons (AAOS), which emphasize observation as the primary treatment and strongly caution against the use of braces and special shoes.⁶ This review reinforces those foundational principles with an updated synthesis of quantitative data.

However, this review builds substantially upon earlier systematic reviews, like that of Rome et al. (2012).²⁴ While that review correctly highlighted the poor quality of evidence and the ineffectiveness of many traditional modalities, the landscape of research has since evolved. The inclusion of more recent RCTs and cohort studies in our analysis provides emerging evidence for the potential benefits of targeted physical therapy and specific orthotics—areas where the evidence

was previously more scarce. Furthermore, the evolution of assessment tools from simple ink-paper footprints to sophisticated 3D-CT scans and instrumented gait analysis has allowed for a more precise understanding of both the natural history and the effects of interventions.⁴⁴

A critical point of discussion arises from this technological advancement. While a 3D-CT scan can measure the FAA with sub-degree precision, its clinical utility in the management of the average child with intoeing is questionable.⁵⁵ The evidence suggests that management decisions are—and should be—driven primarily by the child's age and functional status, not the precise value of their femoral torsion.¹¹ This creates a potential "precision versus utility" dilemma, where the availability of advanced diagnostics could lead to over-investigation and an increased focus on a radiological number rather than the clinical picture of the child. This review suggests that such imaging should be reserved for pre-operative planning in the small number of cases where surgery is being considered, not for routine diagnosis.

CONCLUSION AND RECOMMENDATION

Conclusion

The management of intoeing gait associated with increased femoral anteversion in children should be fundamentally guided by a thorough understanding of its favorable natural history. The standard of care for the vast majority of children is a program of active observation, which includes comprehensive parental education and reassurance. The use of historical treatments such as twister cables, daytime braces, and non-specific corrective shoes is not supported by evidence and should be definitively abandoned. For the specific subset of children who experience significant functional impairments, such as frequent falls or poor motor coordination, a paradigm of functional management is warranted. There is weak to moderate evidence to support the use of specific orthotic devices, particularly gait plates, to improve gait mechanics and reduce tripping. Furthermore, there is emerging evidence from higher-quality studies that targeted physical therapy programs can improve hip muscle balance, range of motion, and postural control, leading to

tangible functional benefits. The decision to intervene should be based on the child's functional status, not solely on the cosmetic appearance of the gait or a radiological measurement.

Recommendations for Future Research

To strengthen the evidence base and refine clinical guidelines, the following areas of research are recommended:

1. **High-Quality Randomized Controlled Trials:** There is an urgent need for well-designed, multi-center RCTs with long-term follow-up to definitively evaluate the efficacy of targeted physical therapy programs compared to active observation in symptomatic children with IFA. These trials should use standardized intervention protocols and a core set of validated functional outcome measures.
2. **Development of Clinical Prediction Rules:** Research should focus on identifying clear, evidence-based criteria to predict which children are most likely to have persistent functional problems and who would, therefore, benefit most from active non-surgical intervention. This would allow for better targeting of rehabilitation resources.
3. **Orthotic Design and Mechanism:** Further research is needed to optimize the design of functional orthotics like gait plates and to better understand their biomechanical mechanisms of action through instrumented gait analysis.
4. **Localized Epidemiological Studies:** To inform local clinical practice and public health planning, epidemiological studies are required to determine the prevalence, etiological distribution, and natural history of intoeing gait within the Indonesian pediatric population.

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