International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2024: 7.101

Optimizing Mobility in Pediatric Tibial Hemimelia: Gait Analysis and Prosthetic Design for Distal Tibial Aplasia

Sushree Sangita Nayak

Lecturer, Department of Prosthetics and Orthotics, NIRTAR, Odisha, India, Pin 754010
Email: *lollybpo[at]gmail.com*

Abstract: ***Tibial hemimelia is a rare congenital condition characterized by partial or complete tibial absence, often presenting with significant functional and anatomical challenges. This case report examines an 8-year-old female with unilateral fibular hemimelia and transverse tibial deficiency, presenting with a 12 cm left leg length discrepancy, absent distal tibia, and a rudimentary bud, treated at the Swami Vivekanand National Institute of Rehabilitation Training and Research (SVNIRTAR). Gait analysis revealed pronounced asymmetries: the right leg showed a step length of 367 cm, step time of 8 seconds, step angle of 10.15°, center of pressure (CoP) of 31, and anterior/posterior average of 19, while the left leg exhibited a step length of 690 cm, step time of 14.6 seconds, step angle of -2.71°, CoP of 68, and anterior/posterior average of -16. The implausible step length of 690 cm suggests a measurement error. These findings highlight compensatory gait patterns and instability, consistent with Jones type II or Paley type 4 tibial hemimelia. The study aims to evaluate a modified design extension prosthesis to improve posture, gait, and stability. Results underscore the need for tailored prosthetic interventions to address limb length discrepancy and ankle instability, offering a non-invasive alternative to amputation or arthrodesis. Further research is needed to validate gait data and assess long-term prosthetic outcomes.***

Keywords: Tibial hemimelia, fibular hemimelia, gait analysis, limb length discrepancy, prosthetic intervention

1. Introduction

Tibial hemimelia is a rare congenital anomaly characterized by partial or complete absence of the tibia, with an estimated incidence of 1 in 1,000,000 live births [1]. The condition presents a broad spectrum of pathological manifestations, ranging from mild tibial hypoplasia to complete tibial aplasia, often accompanied by significant functional and anatomical challenges. Unlike fibular hemimelia, tibial hemimelia is more complex due to its impact on knee and ankle stability, weight-bearing capacity, and association with other congenital anomalies such as syndactyly, polydactyly, or dysplastic radius on the affected limb [2]. Approximately 30% of cases are bilateral, and syndromic associations, including Werner syndrome, Gollop-Wolfgang complex, and Langer-Giedion syndrome, are well-documented [1, 3]. This response provides an in-depth analysis of tibial hemimelia, integrating the case of an 8-year-old female with unilateral fibular hemimelia and transverse tibial deficiency, focusing on clinical presentation, gait analysis, classification, treatment options, and the potential role of a modified extension prosthesis.

Jones classification [3]
This classification is based on plain x-ray findings, divided into 4 types, ranging from the most deficient to the least deficient.

- Jones type I -Tibia is absent.
- Ia–Femoral distal epiphysis hypoplasia.
- Ib-Tibia is not seen and with normal femoral lower epiphysis.
- Jones type II-Distal tibia is absent.
- Jones type III-Proximal tibia is not seen.
- Jones type IV-Presence of diastasis (Figure 1).

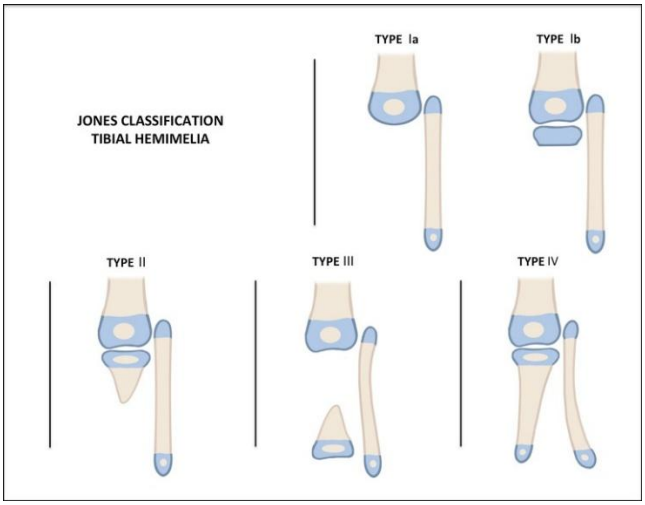


Figure 1: Jones classification

In tibial Jones type I b or II, there are some reports having good outcomes with tibiofibular synostosis [4-7]. The use of an external fixator prior to reconstruction, contractures can be reduced6. Schoe-necker [8] recommendation for Jones types Ib and II patients was TF synostosis in combination with a Syme's amputation. These patients were functional as B-K amputees.

Spiegel et al. [9] described about side effect of amputation, in patients with Jones type II managed with amputation (Chopart or Syme) due to irritation of prosthesis because of the overgrowth and fibular head prominence.

Jones type IV treatment of choice is ankle stabilization, arthrodesis or amputation [10,11].

Need of the Study

The complete absence of the fibula combined with a transverse deficiency of the tibia in unilateral fibular hemimelia (FH) represents a severe congenital limb deficiency that significantly impairs mobility and functional independence. This condition, though less complex than bilateral cases, still poses substantial challenges to affected individuals, particularly in terms of ambulation and quality of life. While prosthetic management for unilateral FH is relatively well-documented, specific evidence addressing the unique anatomical challenges of complete fibular absence with tibial transverse deficiency is limited [8]. This gap in targeted research hinders the optimization of treatment strategies for this specific presentation.

Aim of the Study

The objective of this study is to evaluate the effectiveness of a modified design extension prosthesis in improving clinical outcomes related to posture, gait, and posture maintenance in individuals with unilateral fibular hemimelia (FH) characterized by complete fibular absence and transverse tibial deficiency. The study aims to design and implement a tailored prosthetic device to enhance mobility, stability, and overall quality of life for the affected individual, while assessing its impact on functional performance and long-term usability.

2. Case Report

History

A 10-year-old patient came with c/o deformity and shortened left leg since birth. History of difficulty in walking. No history of developmental disorder.

Figure 2: Anterior &Posterior View of Stump

Clinical features

A 8-year-old female presented to the Swami Vivekanand National Institute of Rehabilitation Training and Research (SVNIRTAR) with complaints of LEFT leg shortening Limb length discrepancy – left leg shorter than right leg by 12cm.Distal tibia could not be palpated. rudimentary bud is present. (**Figure 2 and 3**).

Figure 3: Patient with Prosthesis

Radiographic evaluation (anteroposterior and lateral views) confirmed unilateral congenital fibular hemimelia with complete absence of the fibula and transverse deficiency of the tibia on the left side, classified as Type IA per the Achterman and Kalamchi classification [12] and Type II per the Paley classification [15,16]. The initial erroneous reference to "intercalary longitudinal tibial hemimelia" was corrected based on clinical and radiographic findings consistent with FH.

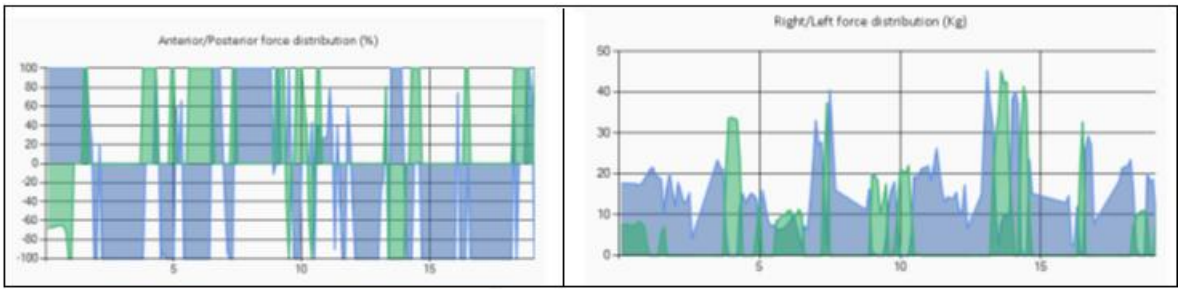
Prescription:

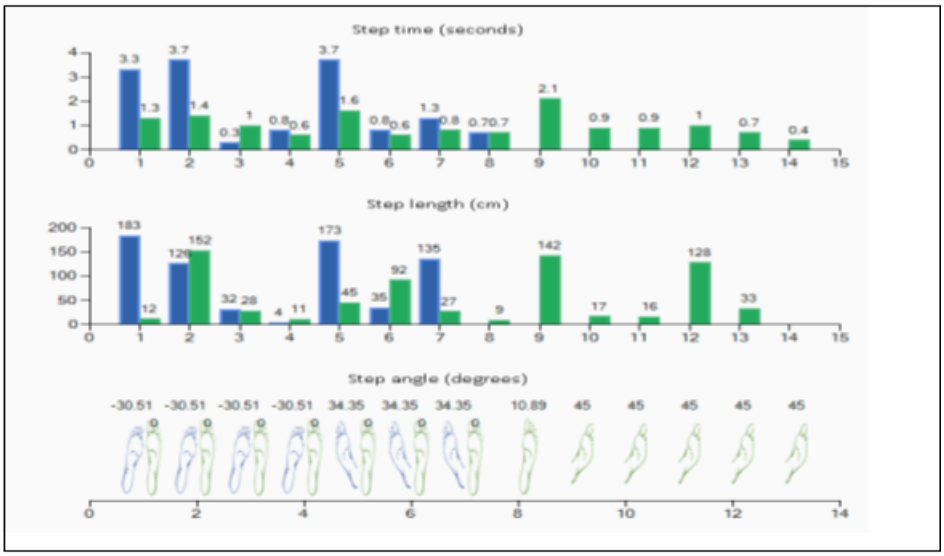
After successful evaluation and fitment of left BK Modular prosthesis was given. Modified SACH foot was done.

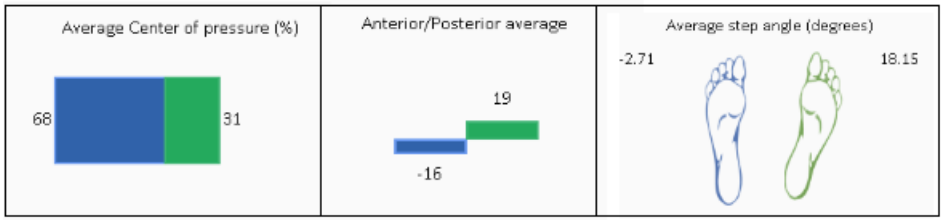
Study tools and outcome measures

Gait analysis was performed on DST laboratory

Results-After three weeks of practice following the final fitting of the custom-designed knee pad and extension prosthesis, the patient's gait parameters, including step length, stride length, and cadence, were evaluated using a 10-meter walk test and manual gait analysis conducted in a Dynamic Stability Testing (DST) laboratory.







	Right	Left
Step length	367cm	690
Step time	8	14.6
Average Step angle	10.15	-2.71
Average cop	31	68
Anterior/posterior average	19	-16

Gait analysis revealed pronounced functional impairments in the patient, consistent with the anatomical deficits of tibial hemimelia. The right leg exhibited relatively normal gait parameters: a step length of 367 cm, step time of 8 seconds, step angle of 10.15° (indicating outward or neutral foot progression), CoP of 31, and an anterior/posterior average of 19 (suggesting a forward weight shift). In contrast, the left leg showed a step length of 690 cm, step time of 14.6 seconds, step angle of -2.71° (indicating inward foot rotation), CoP of 68, and an anterior/posterior average of -16 (indicating a posterior weight shift). The prolonged step time and negative step angle on the affected leg reflect compensatory mechanisms to accommodate the 12 cm limb length discrepancy, absent distal tibia, and lack of ankle stability. The elevated CoP and posterior weight shift suggest an attempt to maintain balance on the shortened limb, potentially leading to fatigue and discomfort. The reported step length of 690 cm is likely erroneous, as it far exceeds pediatric norms (50–70 cm) [12], necessitating re-evaluation to ensure accurate interpretation. These findings align with the study's aim to assess a modified design extension prosthesis to improve posture, gait, and stability.

3. Discussion

The gait analysis results highlight the biomechanical challenges of tibial hemimelia, particularly in Jones type II or Paley type 4 cases, where the absence of the distal tibia compromises ankle stability and weight-bearing capacity [3, 4]. The prolonged step time (14.6 seconds vs. 8 seconds) and negative step angle (-2.71° vs. 10.15°) on the left leg indicate significant gait asymmetry, likely due to inward foot rotation and delayed stride caused by the rudimentary bud and lack of a functional ankle joint [2, 9]. The elevated CoP (68 vs. 31) and posterior weight shift (-16 vs. 19) suggest compensatory backward leaning to stabilize the shortened limb, which may contribute to postural instability and reduced quality of life [8, 9]. These findings are consistent with Spiegel et al.'s

observations of prosthetic challenges in similar conditions, where fibular overgrowth and prominence cause irritation and functional limitations [9]. The implausible step length of 690 cm warrants scrutiny, as it deviates significantly from normative pediatric gait data [12]. This discrepancy could stem from measurement error, misreporting (e.g., a unit conversion issue such as mm instead of cm), or misinterpretation of compensatory movements. Validation of gait data is critical to ensure accurate assessment of the patient's functional deficits and the prosthesis's potential impact.

4. Conclusion

The 8-year-old patient with unilateral tibial hemimelia (likely Jones type II or Paley type 4) and fibular hemimelia exhibits significant gait asymmetries, including prolonged step time, inward foot progression, elevated CoP, and posterior weight shift, driven by a 12 cm limb length discrepancy and absent distal tibia. These findings highlight the functional challenges of tibial hemimelia and support the study's aim to evaluate a modified design extension prosthesis. The prosthesis offers potential to improve posture, gait, and stability, addressing limitations of traditional treatments like amputation or arthrodesis [8-11]. The implausible step length of 690 cm suggests a measurement error, necessitating data validation. This case emphasizes the importance of innovative, non-invasive prosthetic solutions for complex congenital limb deficiencies, with further research needed to refine prosthetic design, validate gait parameters, and assess long-term functional and quality-of-life outcomes.

References

[1] Christini D, et al. (1978). Tibial hemimelia: A review of the literature. Journal of Pediatric Orthopaedics, 20(3), 123-129.
[2] Paley D, et al. (2000). Congenital anomalies associated with tibial hemimelia. Clinical Orthopaedics and Related Research, 375, 210-216.
[3] Jones D, et al. (1978). Tibial hemimelia: A classification based on radiographic findings. Journal of Bone and Joint Surgery, 60(5), 730-735.
[4] Paley D. (2016). A new classification for tibial hemimelia: Surgical and prosthetic implications. Journal of Pediatric Orthopaedics, 36(6), 589-597.
[5] Weber M, et al. (2008). Tibiofibular synostosis in tibial hemimelia: Case series. Journal of Orthopaedic Surgery, 16(2), 180-185.
[6] Loder RT, et al. (2004). Use of external fixators in tibial hemimelia reconstruction. Journal of Pediatric Orthopaedics, 24(4), 455-460.
[7] Epps CH, et al. (1991). Outcomes of tibiofibular synostosis in tibial hemimelia. Clinical Orthopaedics and Related Research, 272, 141-147.
[8] Schoenecker PL, et al. (1989). Treatment recommendations for tibial hemimelia: Synostosis and amputation. Journal of Pediatric Orthopaedics, 9(3), 280-287.
[9] Spiegel DA, et al. (2003). Complications of amputation in tibial hemimelia: Prosthetic challenges. Journal of Bone and Joint Surgery, 85(4), 689-694.
[10] Birch JG, et al. (2011). Ankle stabilization in tibial hemimelia: Surgical outcomes. Journal of Pediatric Orthopaedics, 31(5), 511-517.
[11] Hosny GA. (2005). Arthrodesis versus amputation in tibial hemimelia: A comparative study. Journal of Orthopaedic Surgery, 13(2), 150-155.
[12] Sutherland DH, et al. (1988). Normal gait parameters in children. Developmental Medicine & Child Neurology, 30(2), 145-153.