# Pediatric Running with Lower-Limb Amputation: A Review of the Literature

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## Introduction

The ability to participate in sport and physical activity is an important aspect for the physical, emotional, and social development of a child with limb absence[1]. For children with a physical disability, there are many barriers to participating in sport when compared to their able-bodied peers; one of these barriers is the use and functionality of a prosthesis[1]. For the athletically-inclined child, a prosthesis specifically for running or physical activity is a common request[19]. While running-specific prosthet (RSP) feet have been found to improve the energy cost of running in adult populations[23], evidence suggests that it is not efficacious to simply apply these results to the pediatric population[28].

*The aim of this study is to provide a summary on the current state of research with respect to running in children with lower limb absence.*

## Methods

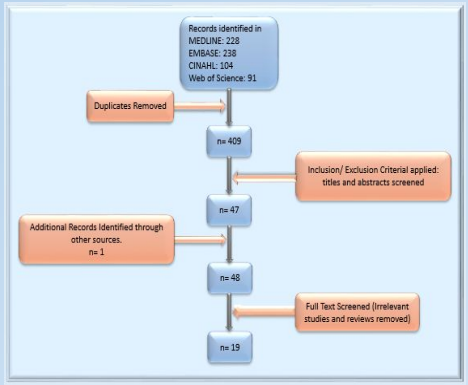
**Literature Search of Embase (1974-Present), Medline (1946-Present), CINAHL (1981-Present), and Web of Science (1950-Present)**

**Search Terms:**
Search terms were applied to include all levels of lower limb amputations in the pediatric population and measures of running or running-related sport participation.

**Inclusion Criteria:**
- Studies involving pediatric subjects with unilateral/bilateral lower limb amputation of either congenital or acquired origin.
- Studies examined running or running-related sports or tasks with a prosthesis, either quantitatively or qualitatively
- Full text article
- English language

**Exclusion Criteria:**
- Over 20 years of age
- Systematic review methodology

**Fig 1. Flow of Information Through Search and Review Process**




## Discussion

### Review Discussion

In the examination of pediatric running literature, variability in the goals and methods of different studies makes it difficult to make definitive conclusions. Another complicating factor is the fact that the main priority of many of the studies is walking gait analysis, and only include running as a secondary comment or analysis.

The following themes were common among the reviewed studies:

**Longer Residuums Improve Running Performance**
- Children with a syme's amputation are often able to function at a normal childhood level [3]
- Improved self-report (PODCI) sports and physical functioning scores were correlated with a longer residual tibia while lower scores were found for above knee amputee subjects [15, 20].
- Running trials (50 yard dash) were conducted for KDA, syme's, and partial foot amputation levels and found improved times with longer residuums compared to normative data [3,14]
- Case studies found that children with Van Nes Rotationplasty have increased SF36 and functional mobility scores compared to TF amputee data and are able to run and function at a competitive athletic level [2, 22, 13]

**It is important to note that all of these studies have been conducted on conventional prosthetic feet. Future research using RSP may change this outcome as individuals with shorter residuums may be able to benefit from high performance RSP, while those with longer residuums (especially partial feet) may lack the build height necessary for RSP.

**Newer Prosthetic Technology Improves Results Sporadically**
- Newer prosthetic technology outperformed traditional prosthetic (SACH) feet in energy cost[7, 25], however different technology was indistinguishable in the majority of biomechanical and performance-based outcomes [5, 15, 19, 29].
- There is currently no means to discriminate between functional differences of prosthetic feet[9] and the inability to find significant differences in spatiotemporal, kinematic, or kinetic data is well documented in the literature [10,12].

**Self-Report Outcomes May be More Efficacious**
- Patients are able to give subjective feedback and distinguish between prosthetic feet regardless of supporting biomechanical or performance based outcomes [12]
- Many studies in this review which used subjective analyses, interviews, or questionnaires in foot preference found better results in newer technology [5,7]
- Self-report and interview measures were used to determine barriers and facilitators to participation in sports and activities. One study found that availability of sports specific prostheses is a facilitator to sports and physical activity in children [1]

### Future Directions

There is currently no published literature focusing on RSPs designed specifically for the pediatric amputee population. Only seven of the articles reviewed have been published since the release of the first pediatric RSP, three of which study RSP in non-pediatric specific versions. Two studies were conducted on the same 16 year old subject for the purpose of developing a digital biomechanical model of a prosthesis[26, 27]. A third article involves a case study of an 11 year old using a modified prosthesis[13]. The lack of information provided on the details of this modification makes comparisons impractical.

Although the gold standard research methodology for clinical treatment trials is a randomized controlled trial (RCT)[17], it is not a feasible practice in assessing the treatment effect of a prosthetic device. Many recent, high quality studies on running in adult amputee subjects utilize a within subjects design to compare prosthetic foot designs as this reduces sources of error related to interpersonal differences and small sample sizes. The addition of able-bodied, age-, body composition-, and training-matched control groups are often used rather than comparison to normative data tables [4,6, 21].

There are currently limitations in the consistent use of performance-based outcome measures as there is presently no psychometric data to support any one outcome measure for this population. For this reason, it is suggested that future research provide justification as to the outcome measures selected. It is important to choose a performance-based outcome measure which is appropriate for the specific population or research setting (eg. meets the needs of the attention spans or ability of a population to follow instructions, or limitations based on research setting such as runway length). Furthermore, it is recommended to supplement performance-based measures with subjective or qualitative data to bring further meaning to the findings. In addition, documented limitations for finding significant biomechanical changes in the amputee population suggest limited value to conducting expensive, time-consuming biomechanical analyses[10].

Studies on adult amputee runners suggests that, with current technology, RSPs may allow similar energy costs of running to able-bodied athletes [23] and it is suggested that RSP models and geometry affect prosthetic function compared to standard prosthetic feet [21, 26]. Since it is noted that the child's gait differs from an adult's [28] and the ability of the child to run and play is important to their health and well-being [1,24], it is therefore crucial that literature be further developed in this area to justify the effects of pediatric RSPs.

**Fig 4. Current Widely-Available Pediatric Running Specific Prosthetic Feet**


## Results

A total of 19 studies were included in the final literature review. These studies range from 1982 to 2019; seven studies have been conducted in the past six years, while nine studies were published over 25 years ago. The majority of lower limb amputation levels were examined in the literature with trans-tibial being the most common (N=14) Twelve different foot types were specified among the studies; SACH feet were studied most, while only three studies examined running specific prosthesis. Throughout the studies running was examined through different qualitative and quantitative means, including biomechanical analysis, performance based tasks, self-report questionnaires, and interviews.

**Fig 2. Timeline of Relevant Literature**

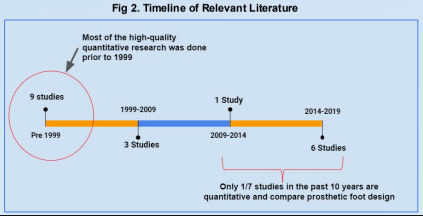
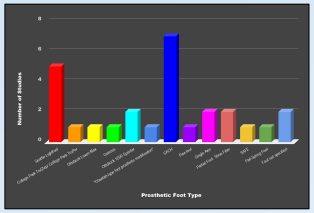



**Fig 3. Prosthetic Foot Types Studied (n=14 studies)**




Many types of prosthetic feet have been examined in pediatric running studies. The SACH foot is the oldest and most commonly studied foot. Only adult RSP have been examined.

## Conclusion

Although there are trends towards better performance outcomes for children with lower levels of amputation, there is a lack of conclusive evidence in the comparison of prosthetic foot types and their impact on running biomechanics or performance. The majority of the biomechanical and performance-based literature related to foot type was conducted over 20 years prior to this review, pre-dating the release of pediatric RSP technology. Thus, indicating the need for further research with more advanced componentry. Improved understanding of the running abilities of the pediatric amputee population and the benefits provided by RSPs by standardizing performance based measures will allow future study comparisons and more generalizable outcomes. This will improve the design of new components, aid in component selection, development of rehabilitation protocols, support funding models, and ultimately benefit the well-being of the child.

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