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TABLE OF CONTENTS

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Dale Berry, CP, FAAOP, LP has practiced prosthetics in Canada, Europe, the Middle East, Haiti and in the U.S.A. Dale is a board-certified prosthetist, a Fellow of the American Academy of Orthotists and Prosthetist and licensed in multiple states. Dale's clinical experiences include 20 years as Vice President of Clinical Operations of the nation's largest provider of prosthetics with over 800 clinics. Dale was also selected to serve as Chairman of the National Academy Microprocessor Forum at Walter Reed Army Medical Center, Team Leader to establish a prosthetic clinic in Kabul Afghanistan to treat landmine victims and Clinical Coordinator to establish a prosthetic clinic at the Albert Schweitzer hospital in Haiti to treat individuals injured with amputation from the 2010 Port-au-Prince earthquake. With over 40 years of experience, Dale has provided care to individuals in numerous countries and settings and is well versed in adapting and applying new technology and techniques to meet the ever-changing demands of patients, referrals and the O&P industry. Dale currently is the owner of Prosthetic Xpert Consultation.

Life Care Planning for Lower Limb Pediatric Prosthetics

By Dale Berry, CP, FAAOP, LP

Keywords: Prosthetics, Pediatrics, Puberty, Fitting

NURSING DIAGNOSES TO CONSIDER
NANDA-I 2021-2023

1. **Domain 4-Activity/Rest. Class 2. Activity/Exercise.**
2. **Domain 13-Growth/Development. Class 1. Growth.**
3. **Domain 13-Growth/Development. Class 2. Development.**

Bradley Pedrick was born with congenital pseudarthrosis of the lower limb which resulted in a broken left tibia. The natural history of the disease is extremely unfavorable and once a fracture occurs, there is a little or no tendency for the lesion to heal spontaneously. (Shah, 2012). Bradley did not walk until he was two years old, and when he did attempt to ambulate, it was with the aid of a brace to support his injured and underdeveloped left foot that was three shoe sizes smaller than the right foot and internally rotated. At the age of 3, Bradley underwent transtibial amputation of the left leg and initiated his introduction to wearing prostheses. Bradley received his initial prosthesis 12 weeks after amputation surgery and over a 10-year span has received a total of 11 prostheses plus 2 socket replacements to accommodate his growth and development.

Bradley Pedrick was born with congenital pseudarthrosis of the tibia leading to eventual amputation of his left leg at age 3. From age 3 to 13 Bradley has received a total of 11 prosthesis plus 2 socket replacement to accommodate his growth and development. (Photo copyright of SWNS Media Group, used with permission)

For the Nurse Life Care Planner developing a Life Care Plan for an adult prosthetic wearer, key factors must be considered related to current prosthetic clinical practice guidelines, coding, billing practices, and regulatory standards to develop a life care plan for an adult suffering from limb loss. (Berry, 2020). When producing a Life Care Plan for the pediatric patient however, there are additional details related to a child's growth, development, activities and availability of pediatric sized components (Cummings, 2006) that also must be considered and applied to ensure an accurate and reliable report.

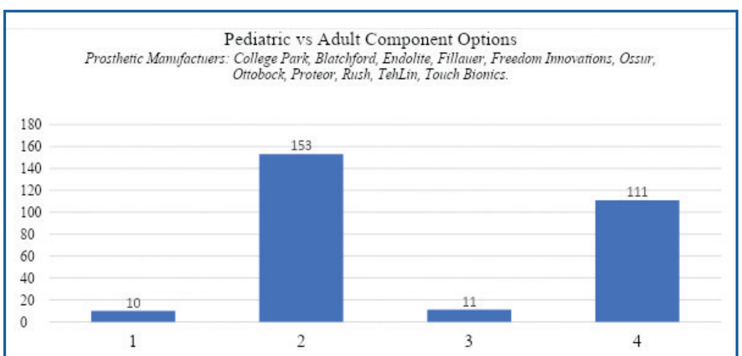
Pediatric cases are statistically most likely related to acquired amputation due to trauma or infection, with traumatic amputations occurring twice as often as amputations from infection. (Le, 2015). Traumatic amputations typically result in a transverse amputation of a single limb while amputation due to infection can result in the amputation of multiple limbs (Oh, 2020, Grunther, 2018). Finger amputations, most notable for children under the age of 2, are the most common traumatic amputation due to door injuries. (Hosteltler, 2005) while amputations for adolescents are most commonly due to power tools or lawnmowers (Vollman, 2006).

Unlike a Life Care Plan for an adult, the life care costs related to pediatric prostheses cannot be applied in a uniform cycle over the patient's entire lifetime. As a child grows to maturity, the style, type, design and costs for medically necessary prosthetic care will need to be adjusted and modified to accommodate normal musculoskeletal growth and development resulting in changes in the patients' height, weight, size, activities, and lifestyle. (McLarney, 2021)

Pediatric Prosthetic Technology Limitations

The current prosthetic design standard for lower extremity prosthetics is endoskeleton, more commonly referred to as modular design. Compared to conventional exoskeletal prosthesis, the modular design provides for improved function, comfort and adjustability, decreased fitting time, enhanced cosmetic appearance and the ability to exchange functional components in the event of damage of an existing component or to upgrade to a newer design. (Kumar, 2011). With the majority of amputations attributed to adults as a result of circulatory disease, (Varma, 2014) the challenge for the pediatric market is that the number of potential patients is smaller for children than it is for adults.

For the manufacturers of prosthetic components, there is a limited and relatively small comparable market to develop, produce and stock multiple sizes and variations of child sized components with such a limited number of potential



clients. Audit of the current on-line catalogs of international and domestic manufacturers of prosthetic components establishes a disparity between the selection of feet and knee components specifically designed for children when compared to the same selection of components for adults. There are 15 times more options of adult prosthetic feet and 10 times more adult knees when compared to pediatric options.

This limited and lack of prosthetic component selection is a contributing factor to the prosthetic replacement cycle for the pediatric patient as some device options have a narrow and very specific functional capability and weight capacity that may only accommodate the pediatric prosthetic wearer for a limited time during their growth and development.

Prosthetic Service Alternatives

Once a prosthetic wearer has been fit with a functional prosthesis, there are four (4) levels of prosthetic services provided over the life cycle of the prosthetic device:

Adjustments, Supplies and Maintenance: Due to routine daily use of the prosthesis combined with normal changes in the patient's residual limb due to growth, the prosthesis will require socket adjustments and prosthetic lengthening. Mitigating factors to necessitate adjustments, supplies and maintenance include (but not limited to) growth height, minor changes in the shapes, size and/or volume of the residual limb or normal wear of the prosthesis due to daily use. Each new prosthesis and replacement socket includes liners, socks and other consumable items, and due to the high frequency of replacement, there is typically no need for additional supplies for the pediatric prosthetic wearer. As for maintenance and repairs, for the active pediatric prosthetic wearer, it is reasonable to accommodate 3-5 hours of prosthetic labor per year, per prosthetic device, to address minor repairs and adjustments.

Component Replacement: There may be times during the child's development that they undergo a "growth spurt" when there is a quick physical growth in height and weight. (Soliman, 2014) Such a growth spurt can create a situation where prosthetic components (foot, knee, connectors) will need to be replaced due to growth even though the component may still be in excellent working order and under warranty.

For lower limb prosthetic wearers, the prosthetic foot must equate to the size of the sound side foot so the child's shoes will fit both the prosthetic and natural foot properly. The growth pattern is constant and varied for children between ages 0-11 while the growth in foot length stabilizes after 12 years of age (Gonzalez-Elena, 2021). As the child grows and requires a larger size shoe to fit the sound side foot, regardless of the age and or pristine condition of the existing prosthetic foot, it will be too small for the child's new shoes and a larger prosthetic foot will be required for the larger shoe size.

In addition, prosthetic feet in particular are fabricated to accommodate a weight range within a 10–20-pound category window. In the event the child gains sufficient weight, even though the child's foot size may remain the same, the prosthetic foot will require replacement if the child's increased weight exceeds the category rating of the existing foot.

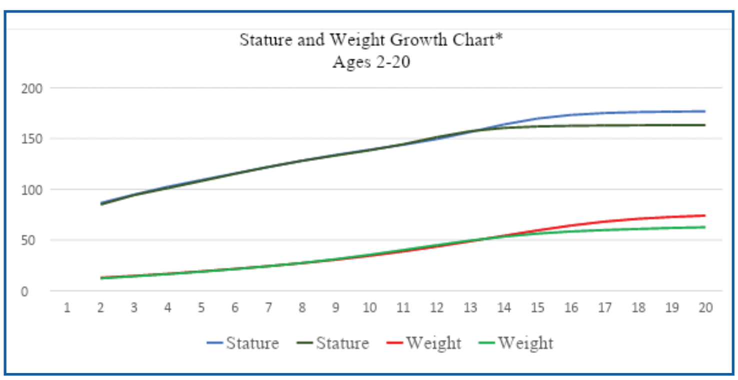
Replacement Socket: Normal and expected changes in the residual limb related to growth will cause the prosthetic socket to become too small while the prosthetic components (knee, foot, ankle) may still be functional and appropriate for the wearer. In this event the prosthetic socket can be replaced and secured to the existing prosthetic components.

Prosthesis Replacement: When the child's growth exceeds the ability to adjust or modify the prosthesis to accommodate comfort and functional needs, a new replacement prosthesis is deemed medically necessary. The new prosthesis would include new components with greater weight limitations and larger sizes with appropriate functional design to accommodate and perform routine activities of daily living.

Growth Influence on Prosthetic Life Cycle

The World Health Organization (WHO) and National Centers for Disease and Prevention (CDC-1) publish stature and weight growth charts for children up to the age of 19 and 20 respectively. These patterns identify an initial uniform growth pattern that reduces after the age of 15 for males and after the age of 13 for females. (de Onis, 2007). When life care planning for pediatric prosthetics, application of these developmental stature and weight patterns provides a basis to project a prosthetic replacement cycle for the development of the child's growth pattern.

Taking into consideration that growth progression on average is more advanced from age 0 to 13 as compared to ages 14 to 20, the replacement cycle of pediatric prosthesis is treated in two categories, pediatric growth phase and adolescent growth phase.

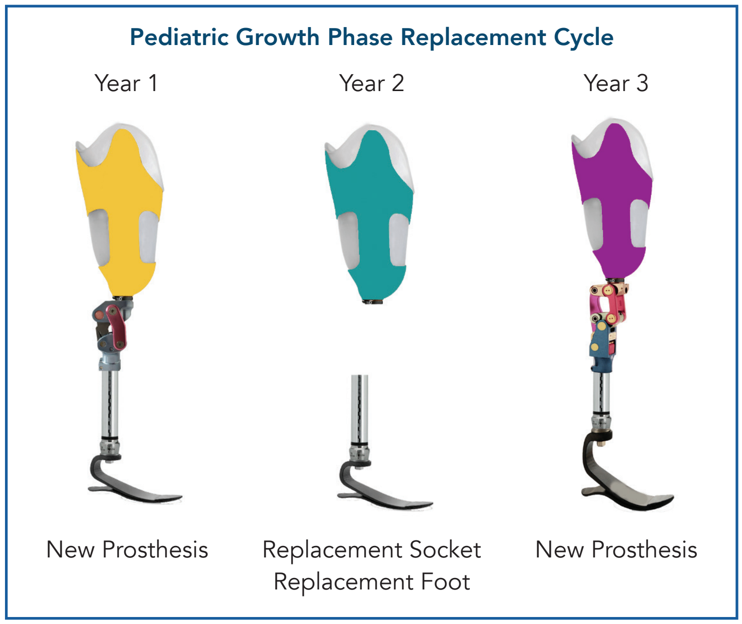


*Content Source: Centers for Disease Control and Prevention, National Center for Health Statistics. Published August 23, 2001. Average growth increases year over year of 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentile. Stature in cm, weight in Kg

Pediatric Growth Phase

For females ages 2-13 and boys ages 2-15, statistically this phase will present the most rapid year over year growth in height and weight and the most constant rate of foot growth (Gonzalez-Elena, 2021). For the lower limb prosthetic wearer, the foot will on average need to be replaced once per year to mirror the growth of the sound side foot and fit in the child's footwear. In addition to foot growth, the socket will also require replacement to accommodate the increases in circumference, length and volume of the residual limb. For an individual with a trans tibial (below knee) amputation, this will require a complete replacement of the prosthesis on a yearly basis.

For the individual with a trans femoral (above knee) amputation, the knee component is modular has an expected life cycle for an active child of 2 years, however the socket and foot will require replacement on a yearly basis to accommodate foot and residual limb growth creating a 2-year life cycle for the knee and one year life cycle for the foot and socket.

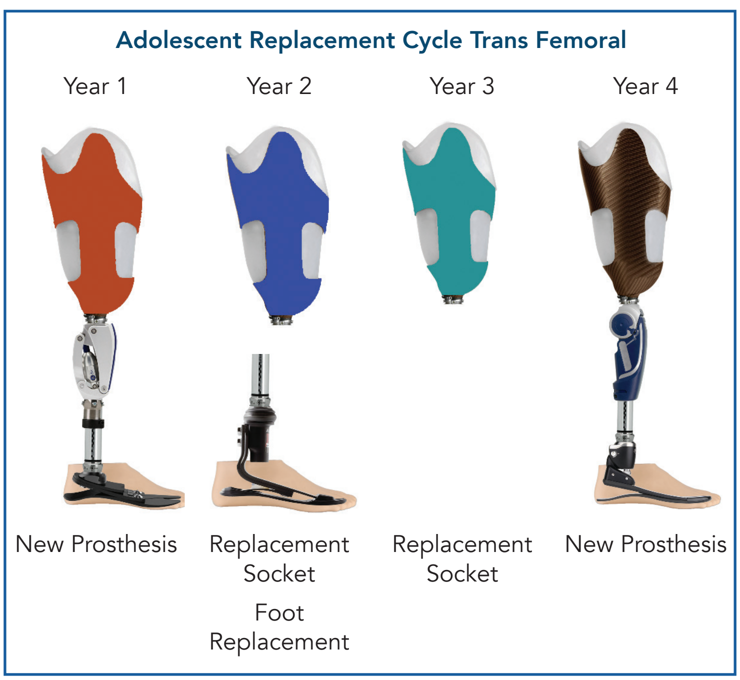


Adolescent Growth Phase

As the pediatric prosthetic wearer reaches the adolescent growth phase, the child will transition to a height and weight which will accommodate a wider range of prosthetic components that are designed for adults. Fourteen-year-old females and males reach an average height 160 cm (5'2") and 164 cm (5' 4") (CDC-2) and an average weight 53.42 Kg and 54.2 Kg respectively (CDC-3).

At or about this time, the growth rate for the adolescent also starts to decline. This combination of access to adult components and reduced rate of growth will in-turn extend the length of the expected reasonable useful life (RUL) of the pediatric prosthesis. For prosthetic feet, a wide variety of adult prosthetic feet are available at a size as small as 21 cm (7 male or 8 female US Size). For the transtibial prosthetic wearer, due to the slower growth rate of the sound side foot, the RUL of the prosthetic foot is estimated to be 18 to 30 months. The residual limb will continue to grow and develop which will require the socket to be replaced on a yearly basis. This equates to a new prosthesis once every two years with a replacement socket at the half-life of the prosthesis.

For transfemoral prosthesis, access to prosthetic knee components designed for adults provides for more durable and functional components that are able to accommodate a wider weight range. (Griffet, 2016) A wide array of adult prosthetic knees of a service life of a minimum of 3 years, (Ottobock) (Ossur), so for the active and growing child, a knee component can be expected to accommodate the wearer for 3-years before having to be replaced for growth



or change in functional or stability requirements. For the individual with a trans femoral (above knee) amputation, the prosthesis can be expected to be replaced once every 3-years, with a foot replacement at the half cycle to accommodate growth in foot size and a replacement socket yearly to accommodate changes in the residual limb.

Transfemoral Prosthesis Fabrication Limitations

For transfemoral prosthesis, the determining factor of whether a knee will accommodate a wearer is the "build height" of the prosthesis, which equates to the measurement of the sound side limb from sole of the foot to the anterior surface of the femoral condyle with the ankle and knee each flexed to a 90° angle. The physical positioning and relative alignment of the prosthetic knee joint to correspond and align with the sound side knee joint is essential for the prosthesis to fit and function as well as provide a symmetrical gait pattern.

The build height of the shin components is a primary consideration when determining if an adolescent transfemoral prosthetic wearer can have access to adult style components. The build height for a transfemoral prosthesis must consider the thickness of the distal end of the prosthetic socket, proximal connector, knee component, distal alignment connector, prosthetic foot and foot shell.

Systematic review of clinical trials identifies that adult transfemoral prosthetic wearers utilizing a microprocessor knee may reduce the number of falls, risk of falling, improve balance, and enable the prosthetic wearer to better perform activities of community ambulation. (Kannenberg, 2014) For children, the microprocessor knee with computerized controls can present limitations as they may be too large and/or heavy and lack necessary durability for active adolescents. (Hall, 2021). To consider an advanced microprocessor knee for an adolescent pediatric prosthetic wearer, depending upon the make and model of knee, foot and connectors, the minimal build height is approximately 38 cm (15") which equates to an individual that is approximately 153 cm (5') or taller. (Marino, 2019)

Special Activity Prosthesis

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For adults, the basis of coverage for determination of medical necessity for the style, model and type of prosthesis is primarily based on the individual's potential functional abilities as measured by the industry standard Functional K Levels. Functional level K1 identifies a household ambulator, K2 a limited community ambulator, K3 an unlimited community ambulator and K4 is specifically established for the child, active adult, or athlete". (LCD L33787).

Although the child prosthetic wearer is categorized as a functional level K4, the primary Activity of Daily Living (ADL) prosthesis is fundamentally designed to provide comfort and mobility to perform routine activities of daily living. Functional capabilities of an ADL prosthesis compared to a Special Activity prosthesis (Image 3) would be similar to comparing everyday shoes worn by a child as compared to special sport cleats to play soccer for example. For special activities or sports, the ADL prosthesis may not have the specific function to or feature for the unique demands of the activity the child wishes to pursue. During sports or special activities, the ADL prosthesis could be exposed to stresses or environment conditions (e.g., dust, dirt, moisture, water) that could damage components, thus, a separate (secondary) prosthesis with activity-specific components that meet a child's needs may be required. (Hall, 2020) In addition to enabling the child to participate in special activities, running specific prostheses have been identified as having a positive impact in promoting children's engagement in sports as well as being worn for a broader range of physical activities. (Hadj-Moussa, 2022)

Although the special activity prosthesis may not have the same degree of daily or constant use as the ADL prosthesis, the replacement cycle is the same as the ADL prosthesis and will require replacement due to growth and change in patient condition.

Conclusion

When producing a life care plan for a child that has undergone a lower limb amputation, it is imperative to take into consideration the style and design of prosthesis that would be considered medically necessary for each year of the child's life as he or she grows in size and stature to adulthood. An accurate cycle for replacement prostheses and replacement sockets must be incorporated into the life care plan to accommodate for the child's expected yearly growth in weight and height, increase in foot size as well residual limb growth. Of equal importance is for the life care plan to consider and to accommodate for the reasonable and anticipated change in the child's activities of daily living and special activities. As children grow and mature, it is a practical expectation that the child will naturally adopt new routines, hobbies, sports and other activities as it relates to prosthetic design, technology and function. These ongoing changes in stature and functional considerations need to be specially addressed and accommodated year by year for accurate pediatric prosthetic life care planning.

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CDC-2 Centers for Disease Control Prevention, Clinical Growth Charts. https://www.cdc.gov/growthcharts/html_charts/statage.htm#males https://www.cdc.gov/growthcharts/html_charts/statage.htm#females

CDC-3 Centers for Disease Control Prevention, Clinical Growth Charts. https://www.cdc.gov/growthcharts/html_charts/wtage.htm#males https://www.cdc.gov/growthcharts/html_charts/wtage.htm#females

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