A review of upper limb pediatric prostheses and perspectives on future advancements

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Abstract

Many complex factors affect whether a child with a congenital upper limb deficiency will wear a prosthetic limb. Ultimately, for a child to wear and use their prosthesis, it must facilitate the effective performance of daily tasks and promote healthy social interactions. Although numerous pediatric devices are available, most provide a single open-close grasp (if a grasping function is available at all) and often offer nonanthropomorphic appearances, falling short of meeting these criteria. In this narrative review, we provide a critical assessment of the state of upper limb prostheses for children. We summarize literature using quality of life measures and categorize driving factors affecting prosthesis use into two main groupings: psychosocial and physical functioning. We define psychosocial functioning as factors related to social inclusion/exclusion, emotional function, independence, and school functioning. Physical functioning is defined as factors associated with the physical use of a prosthesis. The reviewed literature suggests that psychosocial domains of quality of life may be influenced by a congenital limb deficiency, and currently available prostheses provide little benefit in the physical functioning domains. Finally, we discuss technological advancements in adult prostheses that have yet to be leveraged for pediatric devices, including describing recently developed adult electric hands that may improve physical functioning through multiple grasping configurations and provide more hand-like cosmesis. We outline actions necessary to translate similar technologies for children and discuss further strategies to begin removing barriers to pediatric device adoption.

Keywords

pediatric prostheses, quality of life, physical functioning, psychosocial functioning, upper limb, congenital limb deficiency

Introduction

Approximately 1 in every 2800 children in the United States will be born with an upper limb (UL) difference,[1] and nearly 1 in 10,000 live births will present with a transverse upper limb deficiency (ULD).[2] Of these children, those with a below-elbow deficiency may be prescribed an UL prosthesis as young as at age 6–18 months with the intention of helping the child learn to adapt early in life[3]; although early prescription has not been shown to be associated with the frequency of use or wear.[4] Parents influence how often their child wears their prosthesis while they are too young to make these decisions for themselves, and it is not uncommon for parents to view their child's limb difference as a deficiency that must be addressed with an artificial limb.[5] However, when children become old enough to make decisions for themselves, prosthesis abandonment becomes a pervasive issue.[6]

Similar to adult UL prosthesis wearers, device abandonment is common in pediatric populations; however, it is far more prevalent. In a review of 25 years of UL prostheses literature, Biddiss and Chau[7] determined that adult abandonment rates varied from 26% for body-powered devices to 23% for electric devices; yet, for children, these rates were 45% and 35%, respectively. This suggests that development, acceptance, and use of pediatric UL prostheses are complex issues and multiple factors determine whether a child will use or abandon their prosthetic limb.[7] In this narrative review, we will critically assess the state of current prosthetic UL options for children with congenital below-elbow deficiencies and the outcomes reported in literature. Although experimental prostheses, including those developed with 3D printing technologies, have rapidly accelerated in recent years, this narrative review empathizes clinically prescribed devices. Furthermore, we summarize the prevailing technical and social challenges contributing to the high rates of prosthesis abandonment. Finally, we highlight emerging technologies on the clinical horizon, which may begin to remove barriers to prosthesis acceptance for pediatric populations.

Types of pediatric prostheses

Numerous prosthesis options may be prescribed for children with transverse below-elbow deficiencies. These transradial prostheses have several common components that may include a prosthetic socket, liner, terminal device (TD), and harness Figure 1. The socket surrounds the wearer's residual limb and serves as the point of attachment between the prosthesis and the user's body. It is

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custom fabricated and contoured to accommodate the individual's morphology while strategically compressing pressure-tolerant regions on the residual limb to securely suspend the prosthesis. An optional socket liner may be used to improve comfort and suspension in certain cases. The TD is the most distal component that may provide grasping functionality or, in some devices, be included solely for cosmetic appearance. Finally, harnessing is often used to further assist in prosthetic suspension and/or leverage body motion to actuate grasping functions in a TD.

Transradial pediatric prostheses can be categorized into passive (cosmetic) devices that do not provide any grasping functionality and active devices that can be operated to perform grasping functions. Active devices are further subcategorized into body-powered and myoelectric devices (described in detail further). Figure 1 depicts commonly prescribed UL pediatric prostheses. Each category of device provides desirable qualities to the user; however, there are also inherent trade-offs and challenges associated with each. A final category of prostheses is activity-specific devices, which are designed to enable children to participate in specific sports and recreational activities. Although there are a diverse variety of useful activity-specific prostheses, in this review, we will focus on the active and passive devices prescribed for general use in daily living.

Passive devices

A key benefit of passive devices is that they can provide lifelike anthropomorphic appearances. These devices do not actively move to accommodate grasping functions and are typically encased in a silicone or skin-like material that can be made to match the wearer's skin tone and closely resemble an intact hand and/or limb. For children, these prostheses may help in social situations when the child or parent is fearful or anxious about reactions of others to their ULD; however, there is evidence that hiding a limb difference is an ineffective coping strategy.[8] Furthermore, they may help in supporting bimanual tasks or when lifting or playing with large objects.

Body-powered devices

Body-powered prostheses offer wearers the ability to actively control grasp and release movements through a system of cables, elastic bands, and harnessing worn on the upper body. Typically,

scapular motion pulls a cable attached to the TD, which can be set to either open the TD (normally closed device) or close the TD (normally open device). These relatively simple mechanical devices are lightweight, quick to actuate, robust, and simple to use, maintain, and repair. However, their function is limited to a single grasp and release motion, often necessitating compensatory strategies to achieve tasks.[9] Furthermore, many body-powered devices are a split-hook design, bearing little aesthetic resemblance to an intact hand, which may have social implications for the user.[5]

Myoelectric devices

Myoelectric TDs use electromechanical actuators to drive grasping motions. These devices use electromyography (EMG) to control the grasping function of the device. This control technique uses sensors that measure the electrical activity of muscles on the palmar and dorsal aspects of the residual forearm skin. This measured activity is processed by a control system, and the resulting signals command the TD to actuate. Myoelectric devices provide the benefit of control using the muscles of the affected limb, often eliminating the need for harnessing and cables and body/shoulder movements to control the TD. Similar to cosmetic devices, these TDs may also be covered with a silicone cosmetic glove for cosmesis. Myoelectric devices have several practical challenges, including increased weight, reduced robustness,[10] slower actuation speeds, challenges achieving intuitive control,[11] and remembering to recharge the battery[12] when compared with alternate devices. In addition, consistent control is limited by electronic and physiologic characteristics, for example, noisy sensor signals[13] that are sensitive to small displacements on the residual limb,[14] changes in arm posture, and fatigue due to extended muscle use.[15] Commonly, myoelectric TDs are shaped like an intact hand and actuate the first three digits achieving a chuck pinch (three-finger tripod) grasp configuration, which is not suitable for many daily activities; less anthropomorphic devices are also available. Nearly all current pediatric myoelectric devices offer only a single-degree-of-freedom open/closing action.

Quality of life and prosthesis use

Independent from prosthesis research, studies have investigated multiple dimensions related to the quality of life for children with
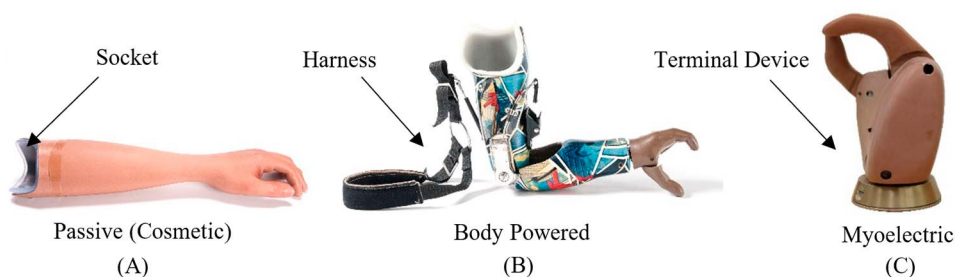

Figure 1. Pediatric prosthetic hand options, with arrows depicting the socket, harnessing, and TD. (A) The cosmetic device provides a realistic appearance. (B) A body-powered device uses compensatory body motion to control the TD. Note: the prosthesis depicted accommodates a higher-level deficiency and includes a mechanical elbow. (C) An electric TD that, when coupled with sensors measuring muscle activity, allows for prehension control. A and B—Photograph courtesy of Shriners Hospitals for Children, Northern California. C—Photograph courtesy of the BLINC Laboratory at the University of Alberta https://blinclab.ca, photograph credit Michael Dawson. TD, terminal device.

ULDs. In this review, we divide the challenges that these children may face into two categories: psychosocial and physical functioning. Table 1 summarizes an analysis of literature reporting the health-related quality of life for children with ULDs using a validated clinical inventory. The pediatric quality of life (PedsQL) inventory was used in several studies[16-18] to compare pediatric individuals with ULDs with the general population.[19-21] This self-reported survey can be completed by either the patient or their parent, is valid for patients aged 2–18 years, and contains 23 items that capture physical, emotional, social, and school functioning.[19,22] It is important to note that PedsQL has been validated in multiple populations, and scoring using patient or parent self-reports has been shown to achieve comparable results and the appropriate statistical significance needed to analyze patient data.[19] Participants respond by providing a score from 0 to 4 to questions that reflect the frequency of events in daily living (0 indicating never and four indicating almost always). Scores are translated to a percentage between 0% and 100% in 25% increments.[19,22] Of interest, of the limited work making these comparisons, PedsQL inventory scores often suggest few statistically and/or clinically significant differences between affected and unaffected patient-matched groups.[16-18]

In addition, Ylimäinen et al,[23] used a cross-cultural health-related quality of life inventory to assess children with limb deficiencies compared with children with common chronic conditions. This inventory was for patients aged 8–16 years and contains five categories to capture physical limitations, emotional function, independence, social inclusion, and social exclusion.[24] Participants respond to the inventory questions through a five-point Likert scale, with response extremes at always (5 points) and never (1 point).[24] This study showed that children with ULDs demonstrated little difference in social exclusion measures compared with children with common chronic conditions while showing improved quality of life measures in the remaining domains.[23]

Psychosocial functioning

ULDs may affect a child on multiple complex levels. Although Table 1 suggests no significant difference in the larger psychosocial domain, James et al[16] showed that social functioning in the school environment can be significantly lower in children with ULDs than in the general population, suggesting there may be a social stigma when children with ULDs interact in a peer environment. Ylimäinen et al[23] additionally found that measures of quality of life in children aged 8–16 years with ULDs (n = 140) are generally higher than children with common chronic conditions (n = 1152) across multiple subdomains (physical limitations, emotional function, and independence, among others), with the exception of social exclusion. This further suggests that having a ULD may come with social and/or exclusionary implications.

It is common for children with UL differences to experience internal stressors related to self-perception and external stressors associated with peer or social interactions, and these can result in anxiety and/or depression.[8] Here, stress may arise not only from the physical differences associated with one's UL but may also be heavily influenced by the aesthetic differences. Internal stress related to aesthetics is more common in teenaged patients, whereas external aesthetic stress is more frequent in younger children.[8] When pediatric patients with UL differences reach adolescence,

Table 1. Pediatric quality of life comparison.						
	Age group (y)	No. of samples (n)	Physical functioning (%)	Emotional functioning (%)	Social functioning (%)	School functioning (%)
Shriners[16]						
General population [19]	2-16	8713	84.08	81.20	83.05	78.27
Wearers	2-20	317	88.5	77.9	82.2	55.1[a]
Nonwearers	2-20	132	88.6	74.3	80.1	46.7[a]
Norway[17]						
General population [20]	13-15	424	91.12	77.15	88.12	78.02
ULD[b]	6-16	46	87	82	87	82
Dutch[18]						
General population [21]	10-12	219	84.9	77.1	86.1	78.7
ULD[b]	10-12	77	87.1	76.0	85.6	78.6
General population [21]	13-14	106	87.3	77.3	90.0	77.0
ULD[b]	13-14	39	89.5	74.9	81.8[c]	74.4

Abbreviation: ULD, upper limb deficiency
Comparison of multiple health-related quality of life studies conducted for the pediatric ULD population. Categories span to assess both physical and psychosocial factors inherent to children with ULDs. Scores for the Shriners, Norway, and Dutch studies[16-18] were obtained through the implementation of pediatric quality of life inventory[22] and compared with their respective general populations.[19-21] Here, participants were asked a set of questions related to the frequency of events during daily activities in which they responded on a scale from 0, indicating never, to 4, indicating almost always. These values were then converted to percentages between 0% and 100% in increments of 25%.[19,22]
[a]Clinically significant difference.
[b]Child-reported results.
[c]Statistically significant difference.

they undergo the same intellectual and emotional changes that other adolescents face, and a limb difference makes this adjustment much more difficult.[25] During the transition from childhood to adolescence, children experience significant development of their self-identity, and positive development can often be correlated with self-esteem during childhood.[26] Coupling this with evidence that peer-related stress spikes around the time a child with an UL difference enters high school, it is evident that finding methods to mitigate external stresses becomes critical during this transitionary period.[8,26]

Teasing and bullying are obvious external stressors that may reinforce the stigma of an UL difference as non-normal and create an us and them mentality.[8,26] However, less obvious, innocent interactions may also have lasting repercussions on a child's mental state. When a child is repeatedly asked about their limb difference, stared at by peers, or even given unique social treatment (i.e. in school or sport), this may affect the child's self-image.[8] Furthermore, these interactions can leave the child feeling singled out, and even meeting new people, when coupled with feelings of self-consciousness or embarrassment, can create further stress. In fact, Franzblau et al[8] found 58% of their 33 pediatric patients with upper differences (ages 6–17 years) associated stress with social interactions. Children are strongly influenced not only by their peers but by how they interact with parents and other adult role models (e.g. teachers and health-care providers). It is not uncommon for a parent to experience emotional strain due to the fact that their child has a congenital limb difference.[8,27,28] Adverse emotional reactions by parents can reinforce a child's feeling of being non-normal or that they have inherent limitations that cannot be overcome.[8,29,30] This can have serious repercussions on self-image, magnify feelings of shame or anxiety, and result in declining social participation.

Although the abovementioned findings focus on a broader population of children with UL differences (independent of prosthesis use), they are highly relevant to complex challenges faced by pediatric prosthesis wearers. There are clear psychosocial implications of having a visibly different limb, which may largely affect adolescents. Similar to the limb deficiency itself, a prosthesis may also create unwanted attention or feelings of being different, which can heavily influence whether it is worn or abandoned. However, these challenges are further complicated as simply wearing a prosthesis to cover or hide one's ULD is not necessarily a desirable outcome because this may be an indication of problematic coping mechanisms.[8]

Physical functioning

Children with ULDs often present little to no significant differences in measures of physical functioning when compared with the general population, as listed in Table 1.[16-18] Furthermore, these individuals have shown increased function when compared with children with common chronic conditions.[23] Specifically evaluating the impact of prosthesis use in this population, James et al[16] performed a study that used both survey-based and functional measures of 489 children with a unilateral congenital below-the-elbow deficiency (321 prosthesis wearers and 168 nonwearers). No clinically relevant differences were found between prosthesis wearers and nonwearers in functional outcomes and quality of life.[16] Furthermore, nonwearers scored higher on the performance of age-appropriate daily tasks than prosthesis wearers, and wearers performed better when not wearing their prosthesis. This drove their conclusion that pediatric prostheses may provide a cosmetic benefit for social acceptance or may be useful tools for specialized activities, but they do not seem to improve performance of daily activities or self-reported quality of life.[16]

The potential physical functioning benefits and drawbacks a prosthesis offers the wearer may be linked to the type of device prescribed. In a retrospective study, it was found that pediatric wearers often prefer body-powered prostheses to myoelectric devices when performing functional tasks.[31] Crandall and Tomhave[31] surveyed the satisfaction of pediatric patients and their parents in relation to prosthesis use during daily activities. In their cohort of 34 wearers (ages 1–12 ½ years), those who wore body-powered devices were able to achieve more functional tasks to the wearers' satisfaction than those who wore passive and myoelectric devices. However, in a long-term follow-up more than a decade later, most of these same subjects were wearing a passive device, suggesting that the grasping function provided by active prostheses offered limited benefit relative to no-grasping function at all. Here again, a trade-off can be made when using passive devices; although they do not provide grasping function, they may provide improved aesthetics to help facilitate social integration. Furthermore, Huizing et al[32] addressed the outcomes of pediatric prosthetic fittings, with 11 of their 20 participants rejecting their device because it provided no functional gain to offset the inconveniences associated with its use. Somewhat intuitively, it has been suggested that the limited function offered by current devices affect their usefulness.[6,32,33] In the absence of sufficient functional gains, pediatric prosthesis wearers may be content with no grasping function and opt for a passive device or choose not to wear a device at all.

When taken together, the decision to wear a prosthesis is dependent on it facilitating improved physical and/or psychosocial functioning. That is, it must provide utility (prosthetic function) and aesthetics that allow the child to feel comfortable participating in social activities with their peers.[5,28,30] The degree to which this is achieved must be sufficient to offset any drawbacks associated with wearing the device, such as increased weight,[6,10,34,35] wearing harnesses, cables, and straps,[34] warmth and perspiration,[34] and the potential for discomfort or tissue irritation.[6,33,34] Furthermore, the financial costs, frequency, and time associated with regular prosthetic maintenance, adjustments to prosthetic fit, and other service-related device requirements can vary across devices and dramatically affect a child's disposition to wearing their device. It is a challenging task to provide a child with a prosthesis that meets these many demands. Unlike the smaller population of children with acquired limb amputations, children born with congenital ULDs learn effective one-handed compensatory strategies for most daily tasks early in life. This in itself may influence a child's willingness to wear a prosthesis because often, there is no real sense of limb loss,[36] although they may feel a sense of being different. Here, a prosthesis is simply an aid rather than a limb replacement, and if it does not actually assist in the often near-normal abilities of the wearer, it will be rejected.[25] Therefore, these children have close-to-normal function, and evidence suggests current prostheses do not further normalize their physical functioning.[16] Therefore,

providing a prosthesis capable of truly augmenting a child's physical functioning, providing satisfactory aesthetics, and overall facilitating social integration remains an important challenge.

Moving forward

Dexterous multigrasp terminal devices

Challenges affecting the pediatric population living with congenital ULDs are often complex and multifaceted. In this population, current prosthetic UL devices are frequently abandoned, which strongly suggests that many fall short of meeting user needs and/or providing sufficient benefit to warrant their wear. It has been suggested that device function and aesthetics (cosmesis) are two key areas contributing to the high rates of rejection.[25] Functionally, unlike the simple open-close grasping offered by active pediatric prostheses, intact hands move with 27 degrees of freedom.[37] Although it is possible to achieve a multitude of complex postures, most daily activities are performed using a limited number of common grasp configurations.[38,39] Nearly 80% of common daily tasks may be accomplished with as few as 6–9 standard grasp configurations.[39] Therefore, we suggest that a significant functional benefit may be provided to pediatric prosthesis wearers if their devices offer a strategic repertoire of grasping configurations. This is not unique to children and closely parallels very active work being performed with adult amputee populations. Similar to pediatric prostheses, adult devices may be cosmetic, body powered, or myoelectric; however, there has also been an acceleration in prosthetic mechatronic technologies resulting in devices that more closely resemble the form and function of intact hands, including offering multiple grasp configurations.[40] As mechatronic technologies continue to evolve, similar smaller-proportioned prostheses are beginning to emerge for pediatric patients. For example, the Vincent Young 3 (Vincent Systems, Karlsruhe, Germany) is sized for children aged 8 years and older and is capable of 13 individual grasp patterns. Similar devices have begun to emerge and will persist as multigrasp prostheses continue to mature and become increasingly available. Furthermore, because these devices typically include individually articulating digits, they may also offer more anthropomorphic hand-like appearances to soften social integration challenges.

Advanced control interfaces

Although multigrasp prostheses are becoming a promising new option for pediatric wearers, several limitations remain to be addressed. Here, prosthesis control interfaces become a crucial factor in device use as in adults, and even the most advanced prostheses rapidly promote frustration and disuse if the control is unintuitive or overly difficult to learn.[12] In conventional myoelectric prostheses, device control presents numerous limitations, namely noisy control signals[13] and sensitivity to small electrode displacements,[14] changes in arm posture, and muscle fatigue,[15] among others. In adult multigrasp hands, standard myoelectric control schemes measure activity in the wearer's residual wrist-flexion and wrist-extension muscle groups as signals to open and close the prosthetic hand, respectively. By cocontracting both muscle sets together, wearers may toggle and select from a list of preprogrammed hand grasp configurations. Here, we suggest that it is doubtful that this toggle-and-select strategy will translate effectively to pediatric devices because it does not replicate typical muscle contraction patterns used for grasping. We argue that toggling creates an increased cognitive load and may negatively reinforce wearers to default to a single primary grasp configuration in an effort to limit the amount of toggling they perform.

Recently, advanced adult prosthesis control strategies have become available that may address limitations in conventional EMG control for pediatric wearers. In the past 10 years, myoelectric pattern recognition techniques transitioned from a promising experimental control strategy to commercially available prosthesis control systems[41-44] that are largely unavailable for the pediatric population. EMG pattern recognition uses multiple electrodes that are applied on the skin's surface over the wearer's affected musculature. Machine learning algorithms are then trained to recognize patterns in the electrical muscle activity and infer the wearer's intended movements.[45] After a short algorithm training session, the real-time classifications of muscle patterns are used to command the appropriate hand movements in a prosthesis.[45] In both the laboratory and real-world prostheses, this technique has largely been shown to improve adult user control over multiple prosthesis movements and/or grasp patterns.[46-48] These techniques continue to evolve to the benefit of more robust control over multiple prosthesis movements with methods now capable of accommodating traditional challenges such as movement and positioning of the prosthesis affecting control consistency.[49-51] However, myoelectric prosthesis control is still beset with limitations, and although more promising than traditional EMG control, it has yet to be translated to pediatric populations.

Other experimental control techniques exclusive to adult populations have begun to emerge as options for intuitive control of multiple prosthesis movements.[12] For example, sonomyography uses a small ultrasound sensor to capture muscle deformations in the affected limb and infer the wearer's intention.[52] Here, image processing and supervised learning algorithms are used to predict intended grasp configurations that generate the pattern of muscle deformation captured in the ultrasound data. This happens in near real time, and the output predictions are encoded to drive the prosthesis.[53] Sonomyography may provide a more accurate control signal because, unlike myoelectrics, it measures activity deep beyond the skin''s surface.[12,52] However, sonomyography, similar to many other experimental control techniques, is still maturing, needs to be further tested as a prosthesis control system, and has yet to be translated to pediatric populations.

A final category of advanced control interfaces that has begun to emerge for adults are neural machine interfaces (NMIs). NMI techniques interface or manipulate the affected neural anatomy of adult prosthetic users to restore physiologically relevant control and sensation. For example, targeted muscles and sensory reinnervation[54,55] redirect affected nerves to new target muscle and skin sites in the residual limb. Then, attempting to move the missing limb creates unique patterns of muscle activity, which are measured and used to intuitively control EMG prostheses.[54] Additionally, stimulation of the reinnervated skin sites can create sensations of touch experienced as occurring in the missing limb[56] and strategic vibration of reinnervated muscles produces

sensations of missing hand movements.[57] Furthermore, multiple peripheral nerve interfaces have been described in literature that measure and decode affected nerve activity for prosthetic control and even stimulate nerves to provide prosthetic sensory feedback.[58,59] Although many NMIs have shown significant promise in achieving intuitive prosthesis control and the restoration of sensation, the invasiveness, requisite surgeries, and experimental nature of these techniques will likely limit their immediate relevancy for pediatric patients.

Current barriers to advanced pediatric devices

As advanced multigrasp prosthetic hands and intuitive control strategies continue to develop, a new subset of challenges unique to pediatric wearers will arise. Device cost is a significant and prohibitive barrier for pediatric populations because children's limbs and bodies are ever-growing. Therefore, unlike adults, where purchasing a single device may be a long-term investment, the cost of children's prostheses must reflect the fact that children outgrow prostheses in a few short years and multiple devices will be purchased over their childhood. Furthermore, with advancements in additive manufacturing, numerous 3D printable UL devices are available; yet, it is important to distinguish these as separate from clinically prescribed devices that receive rigorous engineering development and regulatory approvals before being made commercially available. Child growth presents a further set of challenges in achieving consistent device control. As affected limb proportions change, so will the fit of a prosthetic socket. This may compromise the contact and placement of any sensing technologies and result in diminished, inconsistent, or intermittent device control. Further training and learning will likely play an important role in the success of future prostheses. Individuals with congenital ULDs likely have never had a need to activate their affected muscles because their limb did not finish developing. Although advanced biosensors and intelligent control algorithms may offset some of these difficulties, structured training and learning of these systems will be a necessity for effective use. Finally, device robustness and bulk will foreseeably be important factors. Children will inevitably require robust devices to facilitate the physical nature of childhood play, which include but are not limited to physical durability, waterproof/weather resistance, extended playtimes, and susceptibility to external contaminants. However, robustness typically comes at the cost of more rugged designs with often increased weight and size. Children are more affected by the weight of a device[6,10,35] because they are smaller and do not possess the same strength as a grown adult. Here, creative lightweight low-bulk design principles must be used.

Conclusion

Pediatric UL prosthesis wearers face a number of complex challenges. At present, device abandonment is pervasive because many prostheses fail to offer wearers sufficient benefit to warrant their use. Ultimately, for a child to adopt their device, it must facilitate the effective performance of daily activities and help alleviate stigmas associated with having a limb deficiency. Therefore, both the psychosocial and physical functioning of a child plays a key role. As UL prostheses continue to evolve, there are many technological advancements in the adult arena that have yet to be leveraged for pediatric patients. However, these solutions may not be directly applied to children with ULDs because their challenges are often unique. These may include practical issues related to growth, prosthesis control systems measuring activity in muscles that never actuated an intact limb, and the cost of purchasing multiple devices as a child grows. Furthermore, although technological approaches have the potential to positively affect physical function, psychosocial factors also have a heavy influence on device adoption. Here, children may face both internal and external stressors as they navigate social situations, potential peer exclusion, and both direct and indirect attention drawn to their limb deficiency. Factors such as aesthetics may drive a child to opt for a less functional but more visually appealing prosthesis or choose not to wear a device at all. When taken together, the field of pediatric prostheses may see a technological boom much like adult prostheses have recently experienced. However, several technical, practical, and social challenges must first be addressed to unlock the potential of this next generation of devices.

Declaration of conflicting interest

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Supplemental material

There is no supplemental material in this article.

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