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# *The Impact of Bionic Limbs on Limb Disability Rehabilitation for Disabled Children*

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***Abstract.*** Bionic limbs are artificial devices that mix multiple disciplines and cutting-edge technologies to simulate the structures and functions of human natural limbs. In the current era, many children with limb disabilities still face challenges in daily life due to limb loss. With the continuous progress, innovation, and application of bionic limb technology, an increasing number of disabled children have achieved effective treatment and rehabilitation. However, despite the significant achievements of bionic limbs in the rehabilitation of disabled children, challenges such as insufficient funding, talent shortages, and poor adaptability still need to be solved out. This paper employs a literature review research methodology to investigate the impact of bionic limbs on children's limb disability rehabilitation. Specifically, data analysis is used to examine the importance of bionic limbs in enhancing limb function and fostering psychological development. Additionally, it discusses the challenges faced during the application of bionic limbs and corresponding strategies. The study finds that bionic limbs have a substantial impact on the rehabilitation of disabled children, and it is proposed that bionic limb technology in medical rehabilitation can be further enhanced in the future to enable more children with limb disabilities to recover.

***Keywords:*** Bionic limbs, Disabled children, Limb disability rehabilitation, Psychological rehabilitation

## 1. Introduction

Nowadays, in the United States, a staggering number of individuals are affected by limb loss, with over 2.2 million people currently living with this condition. Projections indicate that the number of disabled individuals will double by 2050, highlighting a severe and growing problem [1]. A recent survey of 306 hospitalized children revealed that 158 cases (51.63%) had comprehensive disabilities, the most common category, while 17 cases (5.56%) had limb disabilities, with a higher prevalence among females [2]. Limb disabilities mainly include cerebral palsy, developmental deformities, and other traumatic injuries accounting for over 60%, with cerebral palsy accounting for approximately 30.80% [3]. In a sample survey of disabled people in Chongqing, China, there were 129,200 disabled children aged 0 to 19, including 13,495 orphans and disabled children, of whom 1,671 were adopted by child welfare institutions [4]. These statistics underscore the

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increasing prevalence of disability and the significant proportion of orphans with disabilities. In this context, bionic limb technology can help more disabled children return to their normal life.

Thus, this paper uses a literature review to study the impact of bionic limbs on limb function recovery and psychological status in disabled children from theoretical and practical aspects, identifies problems based on application and technological development, and proposes feasible solutions, providing theoretical references for researchers.

## 2. Overview of bionic limb technology

The 20th century saw the emergence of bionic technology, driven by the growing demand for robots. With advancements in biomedical engineering, materials science, artificial intelligence, and other related fields, bionic limb technology has gradually matured and become a primary solution for treating disabilities. Many children have recovered through reasonable treatment. To correct limb deformities and reconstruct motor system functions, disabled children typically undergo surgery, with osseous and muscular surgeries being the most common categories, followed by customized braces for postoperative fixation [5]. However, with the development of technology, bionic limb technology has emerged and matured, finding widespread application in practical disability rehabilitation. It has garnered increasing attention, with the number of successful rehabilitation cases growing steadily. By installing bionic limbs, patients can regain limb functionality, achieve self-care, and reintegrate into normal life.

Bionic limbs are sophisticated mechanical devices that integrate multiple disciplines, including materials science, biomedical engineering, biotechnology, biomechanics. They are designed to simulate human movement patterns and limb structures [6]. These devices feature an interface that connects the biological residual limb to electronic devices, enabling both control of prosthetic movement and sensitive feedback. Depending on the type of biological tissue connected, bionic limbs can be categorized into three types: nerve transfer muscle interfaces, direct muscle interfaces, and direct nerve interfaces [7]. The advent of bionic limbs has not only promoted the advancement of surgical techniques but also provided disabled individuals with the means to reverse their condition, regain limb functionality, and pursue their life goals.

## 3. The impact of bionic limbs on disabled children

### 3.1. Impact on limb function recovery

Limb disability refers to the loss of limbs, leading to the loss of inherent functions, damage to the structure and function of the human motor system, which would lead inconveniences in life. Disabled children exhibit poor motor coordination and fine motor skills physiologically, with lower developmental levels in height, weight, shoulder width and so on. Cognitively, they have lower perceptual ability than able-bodied children, weaker sensory perception, and slightly poorer attention and memory [8]. To address these issues, the application of bionic limbs has enabled more disabled children to recover with technological advancement.

In Changsha, Hunan Province, China, a child named Xiaoyou (pseudonym) lost all his four limbs in an accident, falling into despair. His mother recalled that surviving in the ICU was a luxury at the time, but Xiaoyou survived with strong willpower. However, the best treatment required amputation of all four limbs, leaving him in tears daily. The doctor comforted Xiaoyou and his family, stating that modern biotechnology could help him stand and walk again, returning to a normal life. With the care and encouragement of doctors and family, Xiaoyou installed bionic limbs. Through continuous

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adaptation and repeated training, he finally controlled his bionic limbs and stood up. Now, Xiaoyou can go out with friends and sometimes shares his experience online to inspire others suffering from illnesses to rediscover life's direction.

Similarly, in Pennsylvania, USA, Hugh Herr, a climbing prodigy, summited the Rocky Mountains at age 8 and became a top American climber at 17. Unfortunately, in 1982, during a climb of Mount Washington in New Hampshire, he fell into an ice cave during a blizzard, suffering frostbite below the knees. After seven surgeries, he had to amputate, falling into despair and thinking his climbing dream was over. However, he persevered, studying physics at Millersville University in Pennsylvania, then earning a master's degree in mechanical engineering from MIT, becoming a "leader of the bionic era." The bionic limbs he developed not only allowed him to rediscover his childhood hobby but also enabled him to return to climbing years later, achieving his life dream. Moreover, his bionic limbs have helped many disabled children. Combined with brain-computer interfaces, this technology has restored their freedom and brought more possibilities to their lives [9].

These cases fully demonstrate the significant impact of bionic limbs on children's limb rehabilitation, helping many children recover and reintegrate into normal life.

### 3.2. Impact on children's psychological status

As minorities in society, people with disabilities often exhibit two extreme psychological patterns in social interactions: alienation, rejection, or fear [10]. In the subjective value orientation of people with disabilities, their concept of independence often differs from that of able-bodied individuals, creating greater social tension because modern culture divides humans into two worlds: "the world of the healthy" and "the world of the disabled," with both limitations and opportunities. Limb-disabled children typically experience heavy psychological pressure, depression, low mood, reluctance to interact with others, play with peers in the community, and may face discrimination and bullying, leading to further social withdrawal [11]. However, prolonged accumulation of negative emotions is harmful to children's physical and mental health and affects their quality of life and learning. Therefore, while physically rehabilitating, disabled individuals (especially children) can also promote psychological recovery. Bionic limbs can be designed in materials and structure to better support children's psychological rehabilitation, meeting their rehabilitation, emotional, and social needs.

Morphological bionics can be divided into specific and abstract forms. For specific morphological bionics, designers transform cold medical devices into "companion-type partners" using familiar cute animals like rabbits and bears, reducing children's fear when wearing them, diverting attention, stimulating positive emotions, and increasing a sense of security. Abstract bionic forms integrate natural elements, such as abstract leaf texture structures, allowing children to relax and feel closer to nature. Structural bionics incorporate biological internal structures, movement patterns, and growth laws into bionic limb design—for example, finger-shaped grips and vine-like pipeline designs that avoid sharp edges, enhancing safety and children's sense of control over bionic limbs, reducing psychological rejection of the devices.

Functional bionic emotional design imitates biological special functions and environmental adaptability, helping disabled children adapt faster to wearing bionic limbs during rehabilitation. For instance, simulating the "gentle touch" of insects reduces physical pain, weakens treatment-related suffering, and alleviates children's fear and resistance to wearing the devices, improving comfort. By mimicking organic surface textures and visual effects, including fluffy animal shells, texture bionic emotional design uses a tactile system to communicate warmth and security, relieving children's

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stress and easing the psychological strain of recovery. Color bionic emotional design combines bionic limb colors with natural tones, divided into warm and cold colors. Warm tones like orange and bright yellow improve children's negative emotions (depression, inferiority, etc.) caused by illness, stimulating a positive attitude. Cold tones like ocean blue and forest green create a natural connection, reducing fear, suitable for children wearing bionic devices long-term. Additionally, imitating bright, warning color combinations in nature (e.g., black and red on ladybugs) helps children remember functional buttons, quickly master device use, and reduce tension from unfamiliarity [12].

In summary, the humanized design of bionic limbs provides psychological comfort to children, facilitates smooth treatment, reduces therapeutic difficulty, enhances acceptability, and supports their psychological rehabilitation.

## 4. Challenges in the application of bionic limbs for children

In recent years, significant progress has been made in the rehabilitation of disabled children, such as the invention of bionic limbs and growing global attention to this issue. However, challenges in various aspects remain.

First, in terms of funding, the future development of bionic limb technology relies on substantial human resources, funding, and laboratory facilities, requiring significant investment from governments or universities. Thus, funding issues pose a major obstacle to advancing bionic technology [13]. The high cost of developing this technology, requiring significant manpower and material resources, has kept bionic limbs expensive, preventing many patients from accessing rehabilitation due to unaffordability, which largely hinders the popularization and development of bionic limbs.

Second, the safety of bionic limbs is a concern. As the technology continues to evolve and has not yet reached full maturity, mechanical failures or malfunctions may occur during use—for example, causing patients to fall while walking, which is highly dangerous. In addition, poor adaptability during wearing may prevent child patients from independently completing the wearing process, causing life inconveniences.

A most critical issue is society's acceptance and recognition of this emerging bionic limb technology. Current social awareness of bionic limbs is limited, leading many to hold prejudices or remain unaccepting. This also occurs among patients, where unfamiliarity and lack of understanding of bionic limbs can cause psychological fear, pressure, and rejection, leading to refusal or resistance to rehabilitation using bionic limbs. As Professor Hugh Herr noted, bionic limbs repair not disabilities but possibilities broken by reality [9].

In conclusion, bionic limbs still face many problems and challenges in development and application. To address these, the world should enhance public understanding of bionic limbs. Governments and schools should popularize knowledge about bionic limb technology, increase social attention, and reduce societal rejection. Governments and universities should increase project funding to ensure sufficient resources to advance bionic limb technology, improve safety and adaptability, and provide financial subsidies to disabled patients, allowing them to receive treatment at lower costs and enabling more disabled individuals to gain hope from this technology.

## 5. Conclusion

The rise and improvement of bionic limbs have helped many disabled children return to normal life, opening up more possibilities and hope for their lives. In limb rehabilitation, combining bionic surgery with child patients has enabled them to regain limb functionality. In psychological rehabilitation, humanized designs of bionic limbs in five aspects of morphology, structure, function, texture, and color have had important positive impacts on child patients. These ingenious designs effectively reduce children's resistance to bionic limbs and fear of treatment, while enhancing wearers' sense of control and comfort.

Although this paper reveals the impact of bionic limbs on the physical and psychological rehabilitation of disabled children through data analysis and practical cases, limitations exist: First, the number of practical examples demonstrating the positive impact of bionic limbs on physical and psychological aspects is single and lacks universality, potentially affecting the generalizability of conclusions about bionic limb adaptability and post-use effects. Second, the psychological rehabilitation aspect lacks practical investigations, and the absence of real-world application results as support reduces objectivity. Follow-up research should incorporate more practical cases and experimental data for further exploration.

It is hoped that all sectors of society will increase attention and investment in bionic limb technology and children's rehabilitation, provide more funding and talent support, lower the cost of bionic limbs, improve adaptability and safety, continue to promote technological development and social popularization, help more disabled children recover, and bring well-being to society and countless families.

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