

A Functional and Socioeconomic Analysis of State-of-the-Art Prostheses Selection: Comparing Traditional, Myoelectric, and AI-Powered Devices

Sheraya M. Amarasekara

Dubai College, Al Sufouh - Al Sufouh 2 - Dubai, Dubai, 837, UAE; sma.78r@gmail.com

ABSTRACT: Worldwide, an estimated 35–40 million people require prosthetic or orthotic devices. Prosthetic devices are categorized as traditional, myoelectric, or AI-powered. Traditional prostheses are most widely used due to affordability and accessibility, but offer limited functional complexity. Myoelectric prostheses address some limitations by utilizing electromyographic signals from the residual limb to enable more complex movements; however, they require substantial training and remain constrained by needing manual mode switching. AI-powered prostheses build on myoelectric systems by applying machine learning to interpret user intent more accurately, facilitating automatic mode switching and refined control; however, they carry greater financial and weight-related barriers. Although each type offers advantages and drawbacks, selection ultimately depends on user preference, social norms, and clinical feasibility. Current literature tends to focus on individual device types, lacking a holistic, multi-factor comparison to guide informed decision-making. This study addresses that gap by analyzing and comparing literature across five factors: (i) Control and Comfort; (ii) Adaptability; (iii) Cost and Accessibility; (iv) Emotional Benefits and Social Preference; and (v) Durability, Robustness, and Simplicity. Overall, AI-powered devices provide the most advanced control and adaptability, traditional prostheses remain the most durable and accessible, and myoelectric devices occupy an intermediate position. This paper provides a centralized resource supporting evidence-based prosthesis selection.

KEYWORDS: Biomedical Engineering, Biomedical Devices, Prosthetics, Myoelectric, Artificial Intelligence.

■ Introduction

A prosthetic device is any artificial body part that replaces the function or appearance of missing anatomy.¹ These devices are widely used, with over 35–40 million people globally requiring prosthetic or orthotic services. Prosthetic devices can be broadly divided into two types: traditional and digital. A traditional prosthesis is usually a mechanical device that uses physical power from the residual limb to facilitate movement, replacing a body part that is missing or no longer functional.² They could be either passive aesthetic restorations or use a harness and cables for tension-based control.³ They stand within a well-established market and consist of a range of fairly accessible products. However, due to their antiquated nature and reliance on organic sources of force, such as the sound limb, for example,⁴ they have certain shortcomings. These include limited function, given the lack of electronic components, and lower comfort levels.⁵ To mitigate these shortcomings, more developed digital options are arising within the world of biomedical research.

Digital prostheses can be divided into two types: myoelectric prostheses or AI-powered ones. Myoelectric prostheses are externally powered and operate by interpreting electromyographic (EMG) signals from muscles in the residual limb through pairs of electrodes and amplifiers to replicate natural joint movement.⁶ The user trains their muscles to make certain movements/contractions that correspond to actions the prosthetic makes, such as grip changes, opening or closing the

hand, etc.⁷ They require less organic force from the user, and thus less energy, reducing muscle strain.⁸

Myoelectric prostheses use electrodes to capture EMG signals, which can only control one degree of freedom (e.g., opening and closing the hand).⁹ To control other functions, mode switching allows users to change grip types by accurately producing triggers with their residual limb,¹⁰ which can activate other degrees of freedom.¹¹ This can provide a greater range of functionality with a limited number of electrodes, but requires extensive training to employ the technique.

On the other hand, AI-powered digital prostheses refer to any electrical/mechanical device that uses artificial intelligence to interpret gathered data on the movements of a user, producing more natural prosthetic movement. They often use recurrent neural networks to allow real-time decoding of nerve signals for intuitive control, with an accuracy of up to 98% for individual finger and wrist movements of myoelectric hands.¹² In contrast to myoelectric prostheses, AI-powered devices learn from the user's EMG signal data (strength, location, etc.) to ensure that the prosthesis can interpret the user's intended movement more accurately, thus executing the action with higher precision.¹³ Digital prostheses mitigate the shortcomings of traditional devices by generating their own force for movement, having a wider range of more natural, human-like movement, and learning from the user's movements to provide a more comfortable experience.¹⁴ However, they lead to additional constraints related to cost, comfort, and accessibility.¹⁵

Both upper and lower limb prostheses are discussed similarly in the paper, but distinctions are made where needed. Particularly in the analysis of digital devices, control discussions are mainly confined to the upper limb where more precise control is required (in the fingers in comparison with the toes, for example).

Digital solutions are transforming prosthetic care, yet replacing traditional prostheses with their digital counterparts presents limitations. Most of the aforementioned research is often device-specific; those studies that do offer comparison often focus on functional differences rather than comprehensively reviewing all factors related to use. This paper addresses this gap by evaluating traditional, myoelectric, and AI-powered prostheses across five factors: (i) Control and Comfort; (ii) Adaptability; (iii) Cost and Accessibility; (iv) Emotional Benefits and Social Preference; and (v) Durability, Robustness, and Simplicity. The aim is to provide a holistic comparison of all device types, which can be further developed into a centralized repository for prosthesis selection, allowing clinicians and users to make more informed choices. The findings will also help identify future research directions where trade-offs, such as cost and weight, can be mitigated.

■ Factors Affecting Prosthesis Choice

Literature was searched to assess the factors affecting prosthesis choice. Inclusion criteria were as follows: papers published within the 1990–2026 period, papers published in English, and papers directly referencing prostheses, myoelectric prostheses, or AI-powered prostheses. Exclusion criteria were papers older than 1990 and those written in other languages.

Control and Comfort:

Prosthetic control includes the methods through which a patient can manipulate their prosthetic device for use in daily living. Traditional prosthetic devices are typically passive, but can use body-powered harnesses for control.¹⁶ While simple to do, these movements can be conspicuous and unnatural.¹⁷

In contrast, myoelectric prosthetic control is neuromuscular and uses EMG signals. Surface electrodes are placed over the residual limb muscles;¹⁸ patients contract these muscles, and the electrodes detect the electrical nerve impulses produced from this movement, called EMG signals. These EMG signals are used to generate the action to be carried out within the prosthesis.¹⁹ Further, incorporating AI into prosthetics allows machine-learning algorithms to interpret and learn from user data, such as EMG signals, to provide a full range of motion, easier mode switching, and detailed variation in grip strength,^{13,20} thus improving control. For example, the random forest algorithm has been used to classify additional types of motion beyond the two co-contraction movements typically required to ‘trigger’ actions in myoelectric prostheses, allowing higher precision.^{21,22}

While control is essential for enabling precise, reliable movement, the comfort of a prosthesis is critical to ensure continued use.²³ Prosthetic comfort indicates the physical ease or lack of pain experienced during device operation.

All three prosthetic types use similar custom-fit plastic sockets to interface between the body and device. However, traditional sockets can be uncomfortable if they rely on body-powered harnesses, which require high input force from the user.²⁴ Myoelectric sockets have surface electrodes that can feel uncomfortable against the skin and have added weight. AI-powered sockets have the same structure as myoelectric ones, but with added weight due to additional sensors, circuits, and batteries. This often makes digital prostheses heavier than traditional ones.²⁵

Overall, digital devices offer more advanced control compared to traditional ones by using EMG signaling. Further, by improving mode switching using machine-learning algorithms, AI-powered prostheses enable higher precision than myoelectric prostheses.

Adaptability:

Prosthetic adaptability refers to the ability to modify the device's components and functions to suit the user's needs. High adaptability enables the prosthesis to feel like an extension of the body and maximizes functionality.

Traditional prostheses often struggle to mimic natural motion and may function only in binary states (e.g., prosthetic hands often rely on a limited open/close function). Therefore, for different activities, terminal devices (Figure 1) must be used, which form the end part of a prosthesis that interacts with the patient's environment. Their functions vary from activity-specific prostheses (such as for biking or push-ups) to passive restorations that serve only aesthetic purposes.²⁶ While they enhance functionality, frequent removal and replacement can be tedious and expensive.

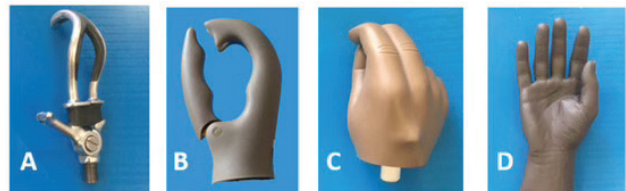


Figure 1: Four examples of terminal devices. (A) Split hook, (B) Adept Prehensor, (C) CAPP hand, (D) Passive cosmesis. Reproduced from ref 26 under Creative Commons License CC BY 4.0. Copyright 2023 The Authors. Published by MDPI.²⁷

Myoelectric prostheses can allow users to perform varied tasks (producing different grip types, opening or closing the hand, etc.) through mode switching. Users will generate ‘triggers’ by flexing different muscles depending on which action they want to execute.^{10, 28} Furthermore, AI-driven prostheses use machine learning (ML) to continuously learn and adapt to a user's movements over time.²⁹ This facilitates more personalized and intuitive control, leading to a more natural feel and improved functionality.¹⁵

Traditional prostheses typically require minimal training to use.³⁰ In contrast, myoelectric control is unintuitive to most and can require extensive training and calibration; AI-based prostheses can overcome this issue by allowing signals to be interpreted more easily over time and progressively ‘learning’ user behavior, enabling more intuitive, fine-grained control.¹⁴ Nonetheless, there is still a learning curve involved in the

training of muscles in the residual limb to control a limb that is no longer there.

Overall, to vary function, traditional prostheses rely on interchangeable terminal devices, while myoelectric prostheses use mode switching. AI-powered prostheses use pattern recognition algorithms to better interpret the user's EMG signals over time, improving the precision of mode switching.

Cost and Accessibility:

The cost of a prosthetic device is related to several factors, including materials, custom fabrication and fitting, technological complexity, ongoing research and development (R&D), as well as clinical services and follow-up care required for proper fitting, calibration, and training. These high costs can not only deter patients from prosthetic devices but also create barriers to access. Since prosthetic use requires specialized services, which are not available at all hospitals, accessibility is limited by capacity constraints at hospitals and proximity to clinics with appropriate resources.³¹ A hospital visit to get a prosthetic device prescribed is a financial burden in and of itself.³²

A major cost associated with prostheses is direct attachment to the human body using a personalized prosthetic socket. The level of personalization required for every prosthetic arm makes high costs inevitable.³³ This raises ethical concerns, especially as those with socio-economic weakness are found to have higher rates of lower-limb amputation, a finding that can be extrapolated to the upper-limb cohort.³⁴

Traditional prostheses, while less expensive than their digital counterparts, still can cost from \$3000 to \$10,000, with those that have more advanced mechanical or hydraulic systems being priced at \$15,000.³⁵ However, global insurance coverage for prostheses remains limited, with many limbs deemed 'medically unnecessary,'³⁶ despite their established role in healthcare. This has led to only 30% of beneficiaries from 2016 to 2019 receiving a prosthetic limb via Medicare, a US-based, federal health insurance program.³⁷ Additionally, through legal and ethical analyses of the reimbursement process in Germany, it was found that the issue of coverage requires "further empirical investigation, a stakeholder dialogue, and maybe even policy changes."³⁸

A myoelectric prosthesis may cost between \$20,000 and \$30,000,³⁵ and an AI prosthesis typically costs around \$190,000.³³ Whilst this study is from 2016, it still serves to exemplify the large difference in cost for AI-powered devices. Thus, digital prostheses remain far more expensive, often making them a luxury item rather than an essential medical device due to their advanced functionality and extensive R&D requirements. However, there have been recent changes in Clinical Commissioning Policies in the UK's National Health Service (NHS) to support multi-grip myoelectric prosthetic hands for eligible patients with congenital or acquired upper limb loss.³⁹

All prosthetic types face ongoing re-purchasing and maintenance costs. In addition, due to growth, children need entirely new prosthetic devices on a short cadence.⁴⁰ These additional costs following the initial investment can accumulate, causing

the price of prosthetic maintenance and replacement to become a lifelong burden rather than a one-off purchase.

Emotional Benefits and Social Preference:

Limb loss can be a traumatic experience;³⁸ therefore, the purpose of a prosthesis is often twofold: functionally replace the missing limb and emotionally support the patient in recovering from their limb loss.⁴¹ Social reactions from the user's environment strongly influence user satisfaction. Both the emotional benefits and social preference significantly affect how a prosthesis affects a user's self-image, social interactions, and quality of life (QOL).³⁸

One study found that prosthesis use can provide ease of social interaction and evade forms of infantilization, indicating that regular use can lead to an amputee feeling self-sufficient.⁴² Another study reported numerous positive lifestyle changes associated with prosthesis use, further evidencing its emotional benefits.⁴³ A study in Saudi Arabia found a positive correlation between psychological adjustment to the prosthesis and the physical component summary and mental component summary of QOL.⁴⁴ Similarly, an international multicenter study of QOL and reasons for abandonment in upper limb prostheses produced similar results; the mean QOL (measured using the EQ-5D) was significantly higher in prosthesis users than non-users.⁴⁵

While prosthetic limbs help some 'blend in' with their social environment, many prefer to cover or conceal their prosthesis for social conformity, as found in a study conducted by Murray.^{42,46} Visible bionic devices can evoke negative reactions among others, such as a lack of understanding or pity. However, positive reactions are also common, such as 'technical fascination' or interest. Whilst positive reactions exist, many digital prosthesis users describe a negative "dual identity" when wearing their device.⁴³ Traditional passive prostheses aim to appear natural and human-like; however, traditional body-powered prostheses can require more pronounced and, in some cases, unnatural movement.⁴⁷ Therefore, they may not be favored by users in public environments. In such cases, digital prostheses can have increased social preference. Advancements in control technology and algorithms will only increase the 'natural' feel of these devices.⁴⁸

Overall, while digital devices can provide increased emotional benefits through superior function, their "cyborg"-like appearance (Figure 2) can lead to rejection. For traditional prostheses, whilst body-powered prostheses lack functionality and can require unnatural movement for control, passive restorations can most closely resemble human anatomy.

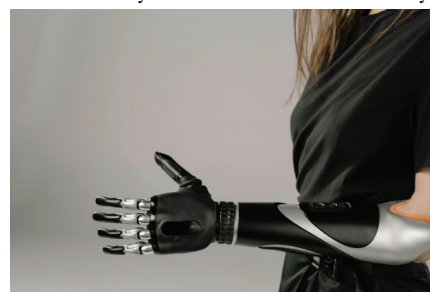


Figure 2: Digital prostheses can have a "cyborg"-like appearance.⁴⁹

Durability, Robustness, and Simplicity :

Prosthetic durability is the ability to withstand wear and damage during use, while robustness refers to maintaining good condition over its lifetime. Simplicity refers to how easily a new user can understand how to use and operate the device.

Traditional prostheses function fairly reliably in outdoor environments and are less sensitive to water, dirt, and extreme temperatures.⁵⁰ They are often more durable and rugged, making them suitable for users who operate in environments where their prosthesis may be susceptible to damage. In contrast, due to their electrical components, digital prostheses, particularly those with microprocessor control, are highly vulnerable to wet environments.⁵¹

Digital prostheses have the added complication of charging, leading to downtime and inconvenience, which is avoided in traditional prostheses. Therefore, the passive nature of traditional prostheses makes them more suitable in low-resource settings, including post-disaster areas, resource-deprived regions, and areas of war.⁵²

Traditional prostheses often excel in simplicity, mostly relying on straightforward, body-powered movement. In contrast, digital prostheses require more complex control skills to be gained through user training. Consequently, digital prosthetic use may not be viable in social groups with low digital literacy rates (such as the elderly, young children, or people in disadvantaged areas). Even for the digitally literate, the learning curve associated with developing the skills required to manipulate digital prostheses can still require extensive training.⁵³

Overall, traditional prostheses are less susceptible to damage. Digital prostheses have the impediment of charging, and their complexity can limit accessibility for the less technologically literate. However, digital prostheses have several dedicated training programs available to mitigate this.^{54,55}

■ Discussion

This study attempted to critically compare the three prosthetic types across five user-focused and function-related factors. The main goal is to establish the key differences between each of the prosthetic types to provide a reference for clinicians and users to make more informed choices when selecting a prosthesis. In addition, key future research directions are covered, with the goal of aligning expectations and areas for improvement. Each section is summarized in a traffic light table to make it easy to see the comparisons highlighted in each section and which prosthetic type is the best in each category.

Control and Comfort:

AI-powered prosthetic limbs are typically preferred in terms of comfort due to their harness-free control, variable grip strength, and automatic mode switching. In contrast, traditional prostheses are either body-powered or passive; for the former, it is difficult to avoid the use of harnesses. However, advances in custom-fit harnessing and new textile materials are improving comfort and hygiene in body-powered models.⁵⁶

As mentioned previously, a key advantage of AI-powered prostheses over myoelectric ones is the fact that ML classifica-

tion systems eliminate manual mode switching for AI-powered prostheses, which is far more convenient than their myoelectric counterparts. Challenges exist in developing AI algorithms for practical use in prostheses. Many factors vary between patients, such as mobility, muscle contraction force, variations in limb position, etc. Therefore, solutions that tailor themselves to patients are required to ensure usability between different patients.⁵⁷ Delay remains a major inconvenience for all digital prostheses, as increased latency can lead to a sluggish user experience and higher abandonment rates. From this perspective, one study used high-density electromyography and a convolutional neural network to adapt itself to unique user voluntary muscle contraction patterns,⁴⁸ leading to a reduced latency of <116 ms. Such optimization techniques are crucial to ensure widespread adoption of digital prostheses.

Further evaluation is required of materials and components in myoelectric and AI-powered digital prostheses, as their high weight can burden users. Progress includes lightweight actuators for application in both upper- and lower-body prostheses.^{58,59} The Össur i-Limb Quantum exemplifies material innovation for lighter prostheses, using titanium to achieve a weight of only 658 grams.⁶⁰

Furthermore, digital prostheses can adapt to muscle signals, allowing users to perform a wider range of tasks compared to traditional prostheses, with a more natural and intuitive feel. However, extensive training is required for patients to manipulate muscles in the residual limb with such precise control. Lack of control is a key factor in prosthetic abandonment, as evidenced by Biddiss and Chau’s study that summarized 25 years of publications, finding that the rejection rate of adult prostheses was 26% for body-powered and 23% for myoelectric, indicating that myoelectric control can slightly increase adherence.^{61,62} However, a much smaller, more recent study reported that non-use rates can be higher for myoelectric users compared to those using traditional prostheses, which is worth noting. It was found that 44% of 25 users rejected their device, with most complaining about comfort and weight.⁶³ This could be a consequence of the aforementioned delay caused by EMG signal processing;⁶⁴ research suggests an optimal delay to be approximately 100–125 ms.⁶⁵ Table 1 provides a summary of the trade-offs between different prosthesis types in terms of control and comfort. Over the five criteria, AI-powered prostheses are superior, followed by myoelectric, and finally traditional.

Table 1: Summary of control and comfort: traditional body-powered systems may require potentially uncomfortable harnesses and offer limited grip-strength variation and modes. Myoelectric and AI-powered systems eliminate harnesses and improve control capabilities, with AI enabling fine-grained grip modulation and automatic mode switching, though both can introduce delays from EMG processing and may increase device mass.

Control and Comfort	Traditional	Myoelectric	AI-Powered
Harness	can include uncomfortable harnesses	no harness	no harness
Mass	light	moderate	heavy
Grip Strength	no/limited variation in grip strength	variation in grip strength with training	fine-grained variation in grip strength without training required
Delay	no delay	delays due to EMG signal processing	delays due to EMG signal processing
Modes	no modes available/require terminal devices	need to manually switch modes	automatic mode switching possible

Adaptability:

Overall, AI-powered prosthetic limbs have superior adaptability due to their intuitive nature and support through training programs. Furthermore, machine-learning algorithms enable automatic mode switching and continuous adaptation to users' muscle signals. In contrast, traditional prostheses are simplistic in terms of versatility and control in daily tasks. Currently, terminal devices are employed for different activities; however, switching them out can be tedious. Alternative adaptability methods for traditional prostheses include a quick-disconnect wrist unit to allow for faster switching of terminal devices.⁶⁶

Furthermore, the development of improved training programs could help traditional prosthetic users adapt to their device more effectively. For example, mobile-game-based prosthetic training methods have already been developed for myoelectric prostheses,³⁸ improving control and user motivation. Translating similar game-based or interactive methods to traditional prostheses could be valuable, as supported by a study on the effects of targeted training for body-powered prostheses, which showed improved functional performance in all users.⁶⁷ Another example includes a study conducted on a group of thirty-two able-bodied participants using body-powered bypass prostheses with an augmented reality (AR) training game, which helped participants improve their control and speed.⁶⁸

Alongside training improvements, advancements in traditional prosthetic design are improving adaptability through modular components. An anatomic study of sixty-five cadaveric humeri enabled the creation of a modular prosthesis system, which allowed users to mix and match components, creating prostheses that were customizable despite not being completely bespoke.⁶⁹ This modular system could extend to other prosthetic types, facilitating cheaper production by reducing detailed personalization while still maintaining an element of user-specific tailoring.

Table 2: Summary of adaptability across prosthesis types. As the devices can adapt to users, improving control over time, AI-powered devices are superior in adaptability. This is furthered by automatic mode switching, allowing prostheses to adjust their behavior to user actions automatically, rather than using manual switching or terminal devices. Reliance on battery life can be insignificant due to single charges being sufficient for a day's use.

Adaptability	Traditional	Myoelectric	AI-Powered
Modes	require terminal devices	uses manual mode switching	uses automatic mode switching
Adapting to the user over time	no adaptation over time	calibrated to muscle signals to perform more varied tasks	adapt and learn from muscle signals over time to perform more varied tasks
Reliance on Battery Life	no batteries required	highly reliant on battery life	highly reliant on battery life

Digital prostheses heavily depend on sensors, power, and battery life, which can pose major safety risks if power fails. Therefore, some advancement in the battery longevity of prostheses should be explored to minimize this issue. The dependence on manufacturers also presents challenges. For example, if a company goes out of business or stops updating a prosthetic model, it can lead to a digital limb becoming useless.⁷⁰ Planned obsolescence has become increasingly common in healthcare;⁷¹ this can be an ethical concern, especially for users who are not financially capable of affording updates or new

parts. People with disabilities are often already vulnerable to poverty; therefore, re-purchasing additional parts over time is often not feasible.³³ Table 2 provides a summary of the trade-offs between different prosthesis types in terms of adaptability. Over the three criteria, AI-powered prostheses are superior, followed by myoelectric, and finally traditional.

Cost and Accessibility:

Overall, traditional prostheses are the most cost-effective and accessible, especially in resource-deprived regions. However, due to persistent insurance reluctance in prosthetic coverage,⁷² even traditional prostheses can be financially inaccessible for many, making digital alternatives even less feasible. Thus, the replacement of traditional prostheses with digital alternatives is largely inhibited by the prohibitive pricing of the industry. The World Health Organization's Standards for Prosthetics and Orthotics has recommended a tiered pricing model to solve this, tailored to varied needs and country resources.⁷³

New manufacturing methods, such as 3D printing, are being tested to increase accessibility by significantly reducing costs. This approach produces designs that can better develop affinities for users through an iterative design approach.⁷⁴ By 3D scanning the residual limb and importing this data into CAD software, we can mitigate the need for excessive labor and allow prosthetists to focus their attention on where it is truly needed — customization. Additive manufacturing allows rapid prototyping, allowing for edits and customization to be carried out more quickly, even possibly at the point of care within the hospital.⁷⁵ The combined effects of reduced labor and improved speed of manufacture can reduce costs. These methods of manufacture have been applied to myoelectric contexts, where the “Mark 5™, Mandro” 3D-printed myoelectric prosthetic hand demonstrated that an affordable, reliable, and durable design can have a “major social impact on patients.”⁷⁶

The simplicity of traditional prostheses makes them more suitable for users with lower competence due to age or other ability-related factors. Therefore, traditional prostheses often do not have structured support, and further research should be conducted into developing structured training programs to help users adapt to their traditional prostheses, particularly in terms of proprioception and agility. Some developments have been made in this area, with studies showing that designated training programs for traditional prosthetic users can help improve control and speed.⁶⁷ Digital prostheses require more training, but the existence of structured training programs helps users adapt more effectively to their devices. Furthermore, since AI-powered prostheses learn the user's behavior over time,²⁹ they could have a less steep learning curve compared to myoelectric prostheses. Game-based and AR training methods have been proposed to make myoelectric skill development more engaging and accessible outside clinical settings, helping users become accustomed to their less intuitive nature.^{51,77}

For those who are technologically illiterate or challenged, such as the elderly, there is a question of whether developing the digital literacy required to operate a digital prosthesis, as

well as enduring the learning curve, is worth the effort. In addition, low-income countries with lower rates of education often have lower rates of digital literacy.⁷⁸ This creates a clear barrier for digital prostheses; more rugged, simple, traditional prostheses may be more accessible to the greater population. Table 3 provides a summary of the trade-offs between different prosthesis types in terms of cost and accessibility. Over the three criteria, traditional prostheses are superior, followed by myoelectric, and finally AI-powered.

Table 3: Summary of cost and accessibility across prosthesis types. Traditional prostheses are the cheapest option and most commonly adopted. The moderate learning curve, while not supported by the learning programs that myoelectric and AI models have, can be easily facilitated by regular use.

Cost and Accessibility	Traditional	Myoelectric	AI-Powered
Cost	cheapest	more expensive	most expensive
Accessibility	most accessible	less accessible	least accessible
Learning Curve	moderate learning curve, without support	steep learning curve, with support	moderate learning curve, with support

Emotional Benefits and Social Preference:

Overall, traditional prostheses offer greater emotional benefits, user social preference, and social conformity; the bionic nature of digital options can be discomfoting, especially in rural contexts where acceptance of amputation and prosthetic usage is low.

Users of all types of prostheses experience some level of improvement in QOL; however, the “cyborg-like “dual identity” created by digital prostheses⁴³ can be harmful to a person’s mental state and self-perception. It is, therefore, important to consider both the positive and unintended negative social consequences of the augmentation of technology in digital prostheses⁷⁹ and perhaps biomedical devices as a whole. This could be changed by making digital prostheses more human-like, such as adopting human skin tones and texture for the unit. For example, Ossur’s i-Limb skin match is a silicone glove that fits over the i-Limb model, which has a very realistic appearance, concealing the myoelectric prosthesis while maintaining function.⁸⁰

For many users, the ability to conceal their prosthesis is critical for their social conformity.⁴² This is fairly difficult for digital prostheses, where their bionic nature is highly visible. However, for traditional prostheses, their appearance is much simpler to conceal, especially for passive prostheses, which are intended to be non-functional but cosmetically identical to a real limb.

The interest or fascination that some outsiders feel when interacting with a digital prosthetic user can have a positive effect on the user themselves.⁴³ While this interest may be prevalent in Western cultures, the digitization of prosthetics may not be favored in rural contexts, such as in Africa or South Asia, due to more traditional beliefs. This is exemplified by a systematic review, which noted that cultural barriers, including the traditional beliefs of Sub-Saharan Africa, hindered the use of prostheses.⁸¹ To ameliorate this, awareness efforts are crucial for rural populations to educate them about the capabilities and benefits of digital prostheses and prosthetics as a whole. This could have some impact in increasing acceptance; however, aiming to change systemic traditional values and opinions can be unfeasible.

Incorporating patient perspectives into prosthetic design can help address social sources of dissatisfaction. Individual choice is both emotionally beneficial to users and is necessary due to the individuality of user needs and wants for prosthetics. Integrating user input into prosthetic design enables the incorporation of social factors into Clinical Practice Guidelines, helping reduce the negative social impacts of prosthetic use.³⁸ Table 4 provides a summary of the trade-offs between different prosthesis types in terms of emotional benefits and social preference. Over the four criteria, traditional prostheses are superior, followed by myoelectric and AI-powered prostheses.

Table 4: Summary of emotional benefits and social preference. AI-powered and myoelectric devices’ advanced function lends a higher level of independence and creates interest among others. However, this fascination may be limited to Western contexts, where advancement in human body-related technology is accepted to a greater degree than in others. Additionally, traditional prostheses can usually be easily concealed to evade stigma.

Emotional Benefits and Social Preference	Traditional	Myoelectric	AI-Powered
	general improvement	general improvement, but increased ‘disability-related feelings of stigma’	general improvement, but increased ‘disability-related feelings of stigma’
Improvement to QOL	moderate to low	high	high
Level of independence provided	high for most traditional prostheses	low	low
Ability to conceal prosthesis	low	high, but may be limited to Western contexts	very high, but may be limited to Western contexts
Technical fascination			

Durability, Robustness, and Simplicity:

Myoelectric and AI-powered prostheses have low resistance to adverse conditions, particularly water, whereas traditional prostheses are less sensitive to weather and terrain. Research into water-resistant digital prostheses is ongoing, with a study developing an EMG sensor that can be used underwater.⁸² It maintained EMG signal quality above and completely submerged below water, evidencing the potential for less sensitive digital prostheses in the future.

Furthermore, charging requirements can inconvenience digital prosthetic users and limit viability in low-resource settings with scarce electricity. Efforts to reduce the energy requirements of prostheses include a study in the context of a powered prosthetic ankle; using a convex optimization formulation, they designed the stiffness of series elastic actuators to minimize energy consumption.⁸³ Table 5 provides a summary of the trade-offs between different prosthesis types in terms of durability, robustness, and simplicity. Over the three criteria, traditional prostheses are superior, followed by myoelectric and AI-powered.

Table 5: Summary of durability, robustness, and simplicity. Traditional prostheses’ low complexity and therefore resistance to adverse conditions allow use in many climates and environments. Their lack of need to charge maintains simplicity.

Durability, Robustness and Simplicity	Traditional	Myoelectric	AI-Powered
Complexity	least complex	more complex	more complex
Resistance to Adverse Conditions	high resistance	low resistance	low resistance
Charging	does not require charging	requires charging	requires charging

Integrative Perspective:

While the five factors have been discussed separately in this study, it is important to acknowledge that complex relationships exist among them. Therefore, this section provides an integrative perspective on these relationships, with the aim of

allowing a user to identify which prosthesis is best suited to their needs.

Training burden affects control, comfort, accessibility and can cause prosthetic abandonment. Issues can arise when users transfer between clinics, and training programs are not consistent. Therefore, training programs should be mandatory (perhaps by government legislation, with potential reimbursement for time and effort) and device-specific (designed by the prosthetic company itself, thus preventing disruption of continuity of care).

Furthermore, user preference cannot be determined by prosthetic function alone, as all factors interact uniquely for each patient. User selection should not be limited by clinic-specific collections of prosthetic devices; users should be able to self-evaluate their preferences and assess all available options before selection. There is currently no standardized way to compare all types of prosthetic modes (traditional, myoelectric, and AI-powered) across economic, functional, and social differences. Studies such as this one are examples of current solutions to this issue; however, such papers are not approachable for public consumption. Therefore, a centralized, patient-facing, online prosthesis comparison platform (with integrated user opinions, product specifications, costs, etc.) can be an accessible way for users to decide which model would be best for their unique needs.

In addition, AI-powered devices have the hidden cost of pre-training through calibration systems, as a brand-new device will not be trained to the specific user. Since the ML algorithms must adapt to each user, this comes at an additional cost.

Research trends are directed towards advancing functionality and control in these devices; however, this innovation can often increase the cost of devices. Innovation and affordability are viewed as separate goals in the industry. Future research should consider whether advanced function can be developed alongside cost reduction strategies to maximize accessibility.

Accessibility is not only financial but also technological. Even where funding is available, devices that require charging, updates, calibration, or high digital literacy may be unsuitable for some users. A solution could involve adapting training programs or offering alternate training programs to accommodate those with lower digital literacy, allowing them to access these more advanced digital devices.

Overall, from the user's perspective, considerations for both upper and lower-limb devices were fairly generalizable to both – have an agreeable appearance, be accepted socially, and function well enough to maintain QOL. The considerations are also mostly generalizable from a clinician's perspective, but the design and manufacturing considerations are different, particularly since lower-limb devices are load-bearing. Prosthetists would use different methods to make devices comfortable and functional. Table 6 summarizes all five factors to provide a succinct summary of this review's findings and can be used as a ready reference for selection.

Current research directions revolve around reducing costs through point-of-care and additive manufacturing; reducing EMG signal processing delays; considering alternative mate-

rials to improve device weight and cost; standardizing training programs, ensuring they are adaptable to users of all digital literacy levels; and improving social acceptance through user-centered prosthetic design.⁸⁴⁻⁸⁷

Table 6: Summary of all five factors. Depending on client choice, socioeconomic conditions, and clinical settings, appropriate prosthesis types can be selected. AI-powered prostheses provide the best control and comfort, and the highest adaptability, but are the heaviest, most complex, battery-dependent, and least accessible due to cost. Traditional prostheses are most affordable, robust, simple, and widely accessible but offer the least control, adaptability, and independence. Myoelectric prostheses stand as an intermediate by improving function over traditional devices but retaining training burden, battery reliance, and reduced robustness, despite remaining more accessible than AI-powered systems.

Cornerstone	Traditional	Myoelectric	AI-Powered
Control and Comfort	Simple control	Advanced control, unintuitive but supported (through training programs)	Advanced control, intuitive and supported (through training programs and ML algorithms)
	Least comfortable	More comfortable	Most comfortable
Adaptability	No modes, binary states	Manual mode switching	Automatic mode switching
	Doesn't adapt to user over time	Doesn't adapt to user over time	Adapts and learns from muscle signals over time to perform more varied tasks
	No reliance on battery life	Reliant on battery life	Reliant on battery life
Cost and Accessibility	Cheapest	Expensive	Most expensive
	Most accessible	Less accessible	Least accessible
	Moderate learning curve, without support	Steep learning curve, with support	Moderate learning curve, with support
Emotional Benefits and Social Preference	General improvement to QOL	General improvement to QOL, but increased 'disability-related feelings of stigma'	General improvement to QOL, but increased 'disability-related feelings of stigma'
	Moderate to low independence	High independence	High independence
	Some types are easy to conceal in public, others are not	Difficult to conceal in public	Difficult to conceal in public
	No technical fascination	High technical fascination, may be limited to Western contexts	High technical fascination, may be limited to Western contexts
Durability, Robustness and Simplicity	Least complex	More complex	More complex
	High resistance to adverse conditions	Low resistance to adverse conditions	Low resistance to adverse conditions
	Doesn't require charging	Requires charging	Requires charging

Case Study:

To exemplify the comparisons made in this paper, three flagship devices, one of each prosthetic type, have been identified and compared across the five factors.

Table 7: The Hosmer 5X Hook, Ottobock Michelangelo Hand, and the Coapt Complete Control Gen2 systems have been compared across the five factors highlighted in the paper.

Type	Traditional	Myoelectric	AI-Powered
Product Name	Hosmer 5X Hook	Ottobock Michelangelo Hand	Coapt Complete Control Gen2 + A compatible prosthetic hand ⁸⁸
Control and Comfort	Body-powered cable/harness control.	Two electrodes capture contraction of forearm muscles. ⁸⁹	Uses two dome electrodes with 8 EMG channels. Continuously adapts to user through 'Adaptive Advance ®' and 'Control Coach ®' calibration systems.
Adaptability	Binary state – open or closed. ⁹⁰	7 different grips possible through particular finger alignment and motorized thumb. ⁸⁹	Uses a continuous-learning algorithm, 'Adaptive Advance ®' that combines previous and new calibration data to adapt and learn to the user's natural changes in control over time.
Cost and Accessibility	\$679.90 (terminal device) only. ⁹¹	~\$60,000-75,000 (prices not available publicly). Ottobock has developed accompanying exercises to train user familiarity (mandatory completion prior to use). ⁹²	~\$70,000-100,000+ (prices not available publicly). Uses a proprietary AI model 'Control Coach ®' to analyze user's calibration data to determine which types of movement will get the least reliable control. Then suggests specific calibration exercises which will add to existing data to allow for better control. This supports user training.
Emotional Benefits and Social Preference	Fairly concealable. Hook however does not mimic human anatomy at all.	Anatomically mimics hand. Can purchase cosmetic, skin-color silicone cover to conceal. ⁹³	Dependent on which compatible hand you select to use with the control system.
Durability, Robustness, and Simplicity	Waterproof up to 1 meter. ⁹⁴	Must be protected from dirt and humidity. Requires charging. ⁹²	Sensitive to 'extreme temperatures' (<-20°C, >45°C) and excessive moisture and dust. Requires charging.

Limitations:

This study is not without limitations. Firstly, the studies referenced here are slightly biased towards upper-limb prostheses, so their findings may not fully apply to lower-limb or mixed amputation contexts. This is because myoelectric/AI-powered systems are more prevalent in upper-limb devices. Secondly, many of the studies are conducted in laboratory settings, and the findings may not fully translate to the real world. For example, cost reductions achieved through specific fabrication methods could be offset by higher insurance mark-ups and changing governance, increasing the final selling price to users. Additionally, prosthesis choice is inevitably controlled by the individual needs of each user. However, we did not suggest which type of prosthesis may be preferable for different user groups (e.g., age, time since amputation, amputation type, user needs). The information in this paper is only presented as a screening tool and is not intended to replace clinician decision-making entirely. Factors such as intended function, age, demographic, etc. should all be taken into account by the treating clinician. Finally, some of the studies referenced here are not recent (median value = 2020), and many studies are conducted in Western contexts. This leads to a bias towards Western populations, which is particularly relevant to *Sec. Emotional Benefits and Social Preference*, where attitudes and beliefs towards prosthetic use differ significantly between Western contexts and the Global South. Furthermore, more recent technologies may be underrepresented.

Conclusion

This paper holistically compared traditional, myoelectric, and AI-powered prostheses on five different factors, spanning function, use, economic impact, social impact, and longevity.

The findings of this paper showed the following:

1. Traditional prostheses: These are the cheapest option and are currently most widely accepted, particularly in rural environments. They are most easily adoptable, due to being the least technically complex and having the strongest durability against adverse conditions. However, they provide the least independence.

2. Myoelectric prostheses: Myoelectric prostheses form an intermediate ground between the simpler traditional prostheses and higher-complexity AI-powered ones. They are better than the former in terms of control but are also more expensive and less accessible; in comparison to the latter, they have less advanced control but are more accessible and cheaper.

3. AI-powered prostheses: In comparison to the other prosthesis types, they excelled in control and comfort due to their advanced control algorithms and had superior adaptability due to their ability to adapt to users. They had some strength in emotional benefits, mainly due to their advanced function, allowing greater QOL. These devices have the greatest potential for development, as current research is primarily directed towards their improvement and advancement.

Patients may lean towards traditional prostheses when access and costs are a concern, but they prefer myoelectric and AI-powered ones when control and independence are of

greater concern. Future research should focus on cost-saving efforts (e.g., greater use of additive manufacturing, on-site manufacturing, alternate material usage, etc.) to increase access; improved insurance and governance policies; optimized control through AI-driven algorithms; faster EMG signal processing; and weight reduction through material choice.

Acknowledgments

Thank you to Vishal Pendse for his guidance and mentorship during the development of this literature review. His support was invaluable to the research process.

References

1. Sansoni, S.; Speer, L.; Wodehouse, A.; Buis, A. Aesthetic of Prosthetic Devices: From Medical Equipment to a Work of Design. In *Emotional Engineering Volume 4*; Fukuda, S., Ed.; Springer International Publishing: Cham, 2016; pp 73–92. https://doi.org/10.1007/978-3-319-29433-9_5.
2. Engdahl, S. M.; Gonzalez, M. A.; Lee, C.; Gates, D. H. Perspectives on the Comparative Benefits of Body-Powered and Myoelectric Upper Limb Prostheses. *J. NeuroEngineering Rehabil.* **2024**, *21* (1), 138. <https://doi.org/10.1186/s12984-024-01436-4>.
3. O'Keeffe, B. Prosthetic Rehabilitation of the Upper Limb Amputee. *Indian J. Plast. Surg.* **2011**, *44* (2), 246. <https://doi.org/10.4103/0970-0358.85346>.
4. Maat, B.; Smit, G.; Plettenburg, D.; Breedveld, P. Passive Prosthetic Hands and Tools: A Literature Review. *Prosthet. Orthot. Int.* **2018**, *42* (1), 66–74. <https://doi.org/10.1177/0309364617691622>.
5. Hafner, B. J.; Willingham, L. L.; Buell, N. C.; Allyn, K. J.; Smith, D. G. Evaluation of Function, Performance, and Preference as Transfemoral Amputees Transition From Mechanical to Microprocessor Control of the Prosthetic Knee. *Arch. Phys. Med. Rehabil.* **2007**, *88* (2), 207–217. <https://doi.org/10.1016/j.apmr.2006.10.030>.
6. Sensinger, J. W.; Hill, W.; Sybring, M. Prostheses—Assistive Technology—Upper. In *Encyclopedia of Biomedical Engineering*; Elsevier, **2019**; pp 632–644. <https://doi.org/10.1016/B978-0-12-801238-3.99912-4>.
7. Elbasiouny, S. M. The Neurophysiology of Sensorimotor Prosthetic Control. *BMC Biomed. Eng.* **2024**, *6* (1), 9. <https://doi.org/10.1186/s42490-024-00084-y>.
8. Kaufman, K. R.; Levine, J. A.; Brey, R. H.; McCrady, S. K.; Padgett, D. J.; Joyner, M. J. Energy Expenditure and Activity of Transfemoral Amputees Using Mechanical and Microprocessor-Controlled Prosthetic Knees. *Arch. Phys. Med. Rehabil.* **2008**, *89* (7), 1380–1385. <https://doi.org/10.1016/j.apmr.2007.11.053>.
9. Hahne, J. M.; Wilke, M. A.; Koppe, M.; Farina, D.; Schilling, A. F. Longitudinal Case Study of Regression-Based Hand Prosthesis Control in Daily Life. *Front. Neurosci.* **2020**, *14*, 600. <https://doi.org/10.3389/fnins.2020.00600>.
10. Heerschoop, A.; Van Der Sluis, C. K.; Otten, E.; Bongers, R. M. Looking beyond Proportional Control: The Relevance of Mode Switching in Learning to Operate Multi-Articulating Myoelectric Upper-Limb Prostheses. *Biomed. Signal Process. Control* **2020**, *55*, 101647. <https://doi.org/10.1016/j.bspc.2019.101647>.
11. Clancy, E. A.; Martinez-Luna, C.; Wartenberg, M.; Dai, C.; Farrell, T. R. Two Degrees of Freedom Quasi-Static EMG-Force at the Wrist Using a Minimum Number of Electrodes. *J. Electromyogr. Kinesiol.* **2017**, *34*, 24–36. <https://doi.org/10.1016/j.jelekin.2017.03.004>.
12. Luu, D. K.; Nguyen, A. T.; Jiang, M.; Drealan, M. W.; Xu, J.; Wu, T.; Tam, W.; Zhao, W.; Lim, B. Z. H.; Overstreet, C. K.; Zhao, Q.

- Cheng, J.; Keefer, E. W.; Yang, Z. Artificial Intelligence Enables Real-Time and Intuitive Control of Prostheses via Nerve Interface. *IEEE Trans. Biomed. Eng.* **2022**, *69* (10), 3051–3063. <https://doi.org/10.1109/TBME.2022.3160618>.
13. Joshi, D. C.; Kumar, P.; Joshi, R. C.; Mitra, S. AI-Enhanced Analysis to Investigate the Feasibility of EMG Signals for Prosthetic Hand Force Control Incorporating Anthropometric Measures. *Prosthesis* **2024**, *6* (6), 1459–1478. <https://doi.org/10.3390/prosthesis6060106>.
 14. Chopra, S.; Emran, T. B. Advances in AI-Based Prosthetics Development: Editorial. *Int. J. Surg.* **2024**, *110* (8), 4538–4542. <https://doi.org/10.1097/JIS9.0000000000001573>.
 15. Engdahl, S. M.; Gates, D. H. Differences in Quality of Movements Made with Body-Powered and Myoelectric Prostheses during Activities of Daily Living. *Clin. Biomech.* **2021**, *84*, 105311. <https://doi.org/10.1016/j.clinbiomech.2021.105311>.
 16. Walters, S.; Seminati, E.; Metcalfe, B.; Bailey, N. Y.; Pegg, E. C. Demystifying Upper Limb Hybrid Prostheses—a Scoping Review. *Front. Rehabil. Sci.* **2025**, *6*, 1610336. <https://doi.org/10.3389/fresc.2025.1610336>.
 17. Guðfinnsdóttir, P. Design and Evaluation of a New Harnessing System for Body-Powered Prostheses. MSc Thesis, TU Delft University of Technology, 2013. <https://resolver.tudelft.nl/uuid:91338545-0a2d-47ee-b9bf-22236d5242b8>.
 18. Dewald, H. A.; Lukyanenko, P.; Lambrecht, J. M.; Anderson, J. R.; Tyler, D. J.; Kirsch, R. F.; Williams, M. R. Stable, Three Degree-of-Freedom Myoelectric Prosthetic Control via Chronic Bipolar Intramuscular Electrodes: A Case Study. *J. NeuroEngineering Rehabil.* **2019**, *16* (1), 147. <https://doi.org/10.1186/s12984-019-0607-8>.
 19. Berning, J.; Francisco, G. E.; Chang, S.-H.; Fregly, B. J.; O'Malley, M. K. Myoelectric Control and Neuromusculoskeletal Modeling: Complementary Technologies for Rehabilitation Robotics. *Curr. Opin. Biomed. Eng.* **2021**, *19*, 100313. <https://doi.org/10.1016/j.cobme.2021.100313>.
 20. Chen, Z.; Min, H.; Wang, D.; Xia, Z.; Sun, F.; Fang, B. A Review of Myoelectric Control for Prosthetic Hand Manipulation. *Biomimetics* **2023**, *8* (3), 328. <https://doi.org/10.3390/biomimetics8030328>.
 21. Vilarino, M.; Moon, J.; Rogner Pool, K.; Varghese, J.; Ryan, T.; V. Thakor, N.; Kaliki, R. Outcomes and Perception of a Conventional and Alternative Myoelectric Control Strategy: A Study of Experienced and New Multiarticulating Hand Users. *JPO J. Prosthet. Orthot.* **2015**, *27* (2), 53–62. <https://doi.org/10.1097/JPO.0000000000000055>.
 22. Burtsev, N. I.; Shagdurov, V. C.; Demkin, I. O. Application of the Random Forest Machine Learning Algorithm for Recognizing Patient Arm Movements While Using a Bionic Prosthesis; St. Petersburg, Russia, 2019; p 020010. <https://doi.org/10.1063/1.5121935>.
 23. Biddiss, E.; Chau, T. Upper-Limb Prosthetics: Critical Factors in Device Abandonment. *Am. J. Phys. Med. Rehabil.* **2007**, *86* (12), 977–987. <https://doi.org/10.1097/PHM.0b013e3181587f6c>.
 24. Andrade, A. O.; Pereira, A. A.; Walter, S.; Almeida, R.; Loureiro, R.; Compagna, D.; Kyberd, P. J. Bridging the Gap between Robotic Technology and Health Care. *Biomed. Signal Process. Control* **2014**, *10*, 65–78. <https://doi.org/10.1016/j.bspc.2013.12.009>.
 25. Lee, K. H.; Bin, H.; Kim, K.; Ahn, S. Y.; Kim, B.-O.; Bok, S.-K. Hand Functions of Myoelectric and 3D-Printed Pressure-Sensored Prosthetics: A Comparative Study. *Ann. Rehabil. Med.* **2017**, *41* (5), 875. <https://doi.org/10.5535/arm.2017.41.5.875>.
 26. Fryer, C.; Michael, J. Upper-Limb Prosthetics: Body-Powered Components. In *Atlas of Limb Prosthetics: Surgical, Prosthetic, and Rehabilitation Principles*; Mosby Year Book: St. Louis, MO, 1992; pp 173–232.
 27. Hussaini, A.; Kyberd, P.; Mulindwa, B.; Ssekitoileko, R.; Keeble, W.; Kenney, L.; Howard, D. 3D Printing in LMICs: Functional Design for Upper Limb Prosthetics in Uganda. *Prosthesis* **2023**, *5* (1), 130–147. <https://doi.org/10.3390/prosthesis5010011>.
 28. Widehammar, C.; Hiyoshi, A.; Lidström Holmqvist, K.; Lindner, H.; Hermansson, L. Effect of Multi-Grip Myoelectric Prosthetic Hands on Daily Activities, Pain-Related Disability and Prosthesis Use Compared with Single-Grip Myoelectric Prostheses: A Single-Case Study. *J. Rehabil. Med.* **2021**. <https://doi.org/10.2340/jrm.v53.807>.
 29. Pilarski, P. M.; Dawson, M. R.; Degris, T.; Carey, J. P.; Chan, K. M.; Hebert, J. S.; Sutton, R. S. Adaptive Artificial Limbs: A Real-Time Approach to Prediction and Anticipation. *IEEE Robot. Autom. Mag.* **2013**, *20* (1), 53–64. <https://doi.org/10.1109/MRA.2012.2229948>.
 30. Mitchell, M.; Gorelick, M.; Anderson, D. I.; Atkins, D. J. Prosthetic Education: Are Occupational Therapy Students' Needs Being Met? *Open J. Ther. Rehabil.* **2014**, *02* (01), 5–11. <https://doi.org/10.4236/ojtr.2014.21002>.
 31. Rajah, J. K.; Chernicoff, W.; Hutchison, C. J.; Gonçalves, P.; Koppainsky, B. Enabling Mobility: A Simulation Model of the Health Care System for Major Lower-Limb Amputees to Assess the Impact of Digital Prosthetics Services. *Systems* **2023**, *11* (1), 22. <https://doi.org/10.3390/systems11010022>.
 32. Rabbitt, L.; Curneen, J.; Hobbins, A.; Gillespie, P.; Dennedy, M. C. Assessing the Financial Burden on Patients and Their Households Attending Hospital Clinics: A Pilot Cross-Sectional Study. *BMC Health Serv. Res.* **2025**, *25* (1), 1390. <https://doi.org/10.1186/s12913-025-13503-0>.
 33. Kwek, E.; Choi, M. Is a Prosthetic Arm Customized PRADA? A Critical Perspective on the Social Aspects of Prosthetic Arms. *Disabil. Soc.* **2016**, *31* (8), 1144–1147. <https://doi.org/10.1080/09687599.2016.1235308>.
 34. Ferguson, H. J. M.; Nightingale, P.; Pathak, R.; Jayatunga, A. P. The Influence of Socio-Economic Deprivation on Rates of Major Lower Limb Amputation Secondary to Peripheral Arterial Disease. *Eur. J. Vasc. Endovasc. Surg.* **2010**, *40* (1), 76–80. <https://doi.org/10.1016/j.ejvs.2010.03.008>.
 35. McGimpsey, G.; Bradford, T. *Limb Prosthetics Services and Devices: Critical Unmet Need: Market Analysis*; National Institute of Standards and Technology (NIST), 2017. https://www.nist.gov/system/files/documents/2017/04/28/239_limb_prosthetics_services_devices.pdf (accessed 2025-12-08).
 36. McLarney, M.; Pezzin, L. E.; McGinley, E. L.; Prosser, L.; Dillingham, T. R. The Prevalence of Lower Limb Loss in Children and Associated Costs of Prosthetic Devices: A National Study of Commercial Insurance Claims. *Prosthet. Orthot. Int.* **2021**, *45* (2), 115–122. <https://doi.org/10.1177/0309364620968645>.
 37. United States Government Accountability Office. *Rehabilitation Services and Outcomes for Medicare Beneficiaries*; GAO-25-106406; United States Government Accountability Office: Washington, D.C., 2024. <https://www.gao.gov/assets/gao-25-106406-highlights.pdf> (accessed 2025-12-08).
 38. Baumann, M. F.; Frank, D.; Kulla, L.-C.; Stieglitz, T. Obstacles to Prosthetic Care—Legal and Ethical Aspects of Access to Upper and Lower Limb Prosthetics in Germany and the Improvement of Prosthetic Care from a Social Perspective. *Societies* **2020**, *10* (1), 10. <https://doi.org/10.3390/soc10010010>.
 39. NHS England. *Clinical Commissioning Policy: Multi-Grip Prosthetic Hand (All Ages)*; NHS England: London, UK, 2022. <https://www.england.nhs.uk/wp-content/uploads/2022/09/2009-cli>

- nicial-comm-policy-multi-grip-prosthetic-hand-all-ages-1.pdf (accessed 2025-12-08).
40. Dickinson, A.; Gates, L.; Metcalf, C.; Spurway, C.; Kheng, S.; Heang, T.; Sam, B.; Harte, C.; Simpson, S.; Worsley, P.; Ostler, C.; Donovan-Hall, M.; Channon, A. Understanding Maintenance, Repair, and Replacement of Prosthetic Limbs Using Routinely-Collected Data: A Retrospective Study over Three Decades in Cambodia. *J. Glob. Health* **2025**, *15*, 04135. <https://doi.org/10.7189/jogh.15.04135>.
 41. Volpini Lana, M. R.; Maia, J. P.; Ribeiro, J. P. Current Insights into Lower Limb Prostheses: Brazilian Users' Perceptions on the (Re) Construction of Body Image and Identity. *Ir. J. Occup. Ther.* **2025**, *53* (1), 4–11. <https://doi.org/10.1108/IJOT-06-2024-0029>.
 42. Murray, C. D. The Social Meanings of Prosthesis Use. *J. Health Psychol.* **2005**, *10* (3), 425–441. <https://doi.org/10.1177/1359105305051431>.
 43. Bretschneider, M.; Meyer, B.; Asbrock, F. The Impact of Bionic Prostheses on Users' Self-Perceptions: A Qualitative Study. *Acta Psychol. (Amst.)* **2023**, *241*, 104085. <https://doi.org/10.1016/j.actpsy.2023.104085>.
 44. Alessa, M.; Alkhalaf, H. A.; Alwabari, S. S.; Alwabari, N. J.; Alkhalaf, H.; Alwayel, Z.; Almoaibed, F. The Psychosocial Impact of Lower Limb Amputation on Patients and Caregivers. *Cureus* **2022**. <https://doi.org/10.7759/cureus.31248>.
 45. Yamamoto, M.; Chung, K. C.; Sterbenz, J.; Shauver, M. J.; Tanaka, H.; Nakamura, T.; Oba, J.; Chin, T.; Hirata, H. Cross-Sectional International Multicenter Study on Quality of Life and Reasons for Abandonment of Upper Limb Prostheses. *Plast. Reconstr. Surg. - Glob. Open* **2019**, *7* (5), e2205. <https://doi.org/10.1097/GOX.0000000000002205>.
 46. Widehammar, C.; Pettersson, I.; Janeslätt, G.; Hermansson, L. The Influence of Environment: Experiences of Users of Myoelectric Arm Prosthesis—a Qualitative Study. *Prosthet. Orthot. Int.* **2018**, *42* (1), 28–36. <https://doi.org/10.1177/0309364617704801>.
 47. Engdahl, S. M.; Lee, C.; Gates, D. H. A Comparison of Compensatory Movements between Body-Powered and Myoelectric Prosthesis Users during Activities of Daily Living. *Clin. Biomech.* **2022**, *97*, 105713. <https://doi.org/10.1016/j.clinbiomech.2022.105713>.
 48. Tam, S.; Boukadoum, M.; Campeau-Lecours, A.; Gosselin, B. Intuitive Real-Time Control Strategy for High-Density Myoelectric Hand Prosthesis Using Deep and Transfer Learning. *Sci. Rep.* **2021**, *11* (1), 11275. <https://doi.org/10.1038/s41598-021-90688-4>.
 49. cottonbro studio. *Close-up of a Woman Wearing a Sleek, Modern Prosthetic Arm. Studio Shot Emphasizes Technology and Innovation.*; 2020. <https://www.pexels.com/photo/close-up-shot-of-a-woman-with-prosthetic-arm-6153078/> (accessed 2026-06-06).
 50. Trejo-Letechipia, M. A.; Rodriguez-Sanchez, D. A.; González-González, R. B.; Perez-Sanpablo, A. I.; Arizmendi-Morquecho, A. M.; Lara-Ceniceros, T. E.; Bonilla-Cruz, J.; Cortes-Ramirez, J. A. Design and Manufacturing of a Body-Powered Hook with Force Regulation System and Composite-Based Nanomaterials. *Appl. Sci.* **2021**, *11* (9), 4225. <https://doi.org/10.3390/app11094225>.
 51. McDonald, C. L.; Kahn, A.; Hafner, B. J.; Morgan, S. J. Prevalence of Secondary Prosthesis Use in Lower Limb Prosthesis Users. *Disabil. Rehabil.* **2024**, *46* (5), 1016–1022. <https://doi.org/10.1080/09638288.2023.2182919>.
 52. McFarland, L. V.; Winkler, S. L. H.; Heinemann, A. W.; Jones, M.; Esquenazi, A. Unilateral Upper-Limb Loss: Satisfaction and Prosthetic-Device Use in Veterans and Servicemembers from Vietnam and OIF/OEF Conflicts. *J. Rehabil. Res. Dev.* **2010**, *47* (4), 299. <https://doi.org/10.1682/JRRD.2009.03.0027>.
 53. Damercheli, S.; Morrenhof, K.; Ahmed, K.; Ortiz-Catalan, M. Performance in Myoelectric Pattern Recognition Improves with Transcranial Direct Current Stimulation. *Sci. Rep.* **2024**, *14* (1), 11744. <https://doi.org/10.1038/s41598-024-62185-x>.
 54. Widehammar, C.; Lidström Holmqvist, K.; Hermansson, L. Training for Users of Myoelectric Multigrip Hand Prostheses: A Scoping Review. *Prosthet. Orthot. Int.* **2021**, *45* (5), 393–400. <https://doi.org/10.1097/PXR.0000000000000037>.
 55. Winslow, B. D.; Ruble, M.; Huber, Z. Mobile, Game-Based Training for Myoelectric Prosthesis Control. *Front. Bioeng. Biotechnol.* **2018**, *6*, 94. <https://doi.org/10.3389/fbioe.2018.00094>.
 56. Vujaklija, I.; Farina, D.; Aszmann, O. New Developments in Prosthetic Arm Systems. *Orthop. Res. Rev.* **2016**, *Volume 8*, 31–39. <https://doi.org/10.2147/ORR.S71468>.
 57. Parajuli, N.; Sreenivasan, N.; Bifulco, P.; Cesarelli, M.; Savino, S.; Niola, V.; Esposito, D.; Hamilton, T. J.; Naik, G. R.; Gunawardana, U.; Gargiulo, G. D. Real-Time EMG Based Pattern Recognition Control for Hand Prostheses: A Review on Existing Methods, Challenges and Future Implementation. *Sensors* **2019**, *19* (20), 4596. <https://doi.org/10.3390/s19204596>.
 58. Yang, H.; Tao, Z.; Yang, J.; Ma, W.; Zhang, H.; Xu, M.; Wu, M.; Sun, S.; Jin, H.; Li, W.; Wang, L.; Zhang, S. A Lightweight Prosthetic Hand with 19-DOF Dexterity and Human-Level Functions. *Nat. Commun.* **2025**, *16* (1), 955. <https://doi.org/10.1038/s41467-025-56352-5>.
 59. Tran, M.; Gabert, L.; Hood, S.; Lenzi, T. A Lightweight Robotic Leg Prosthesis Replicating the Biomechanics of the Knee, Ankle, and Toe Joint. *Sci. Robot.* **2022**, *7* (72), eabo3996. <https://doi.org/10.1126/scirobotics.abo3996>.
 60. Siegel, J. R.; Harwood, J. K.; Lau, A. C.; Brenneis, D. J. A.; Dawson, M. R.; Pilarski, P. M.; Schofield, J. S. A Performance Evaluation of Commercially Available and 3D-Printable Prosthetic Hands: A Comparison Using the Anthropomorphic Hand Assessment Protocol. *BMC Biomed. Eng.* **2024**, *6* (1), 11. <https://doi.org/10.1186/s42490-024-00086-w>.
 61. Yamamoto, M.; Chung, K. C.; Sterbenz, J.; Shauver, M. J.; Tanaka, H.; Nakamura, T.; Oba, J.; Chin, T.; Hirata, H. Cross-Sectional International Multicenter Study on Quality of Life and Reasons for Abandonment of Upper Limb Prostheses. *Plast. Reconstr. Surg. - Glob. Open* **2019**, *7* (5), e2205. <https://doi.org/10.1097/GOX.0000000000002205>.
 62. Biddiss, E. A.; Chau, T. T. Upper Limb Prosthesis Use and Abandonment: A Survey of the Last 25 Years. *Prosthet. Orthot. Int.* **2007**, *31* (3), 236–257. <https://doi.org/10.1080/03093640600994581>.
 63. Salminger, S.; Stino, H.; Pichler, L. H.; Gstöttner, C.; Sturma, A.; Mayer, J. A.; Szivak, M.; Aszmann, O. C. Current Rates of Prosthetic Usage in Upper-Limb Amputees – Have Innovations Had an Impact on Device Acceptance? *Disabil. Rehabil.* **2022**, *44* (14), 3708–3713. <https://doi.org/10.1080/09638288.2020.1866684>.
 64. Wang, X.; Ao, D.; Li, L. Robust Myoelectric Pattern Recognition Methods for Reducing Users' Calibration Burden: Challenges and Future. *Front. Bioeng. Biotechnol.* **2024**, *12*, 1329209. <https://doi.org/10.3389/fbioe.2024.1329209>.
 65. Farrell, T. R.; Weir, R. F. The Optimal Controller Delay for Myoelectric Prostheses. *IEEE Trans. Neural Syst. Rehabil. Eng.* **2007**, *15* (1), 111–118. <https://doi.org/10.1109/TNSRE.2007.891391>.
 66. Bates, T. J.; Ferguson, J. R.; Pierrie, S. N. Technological Advances in Prosthesis Design and Rehabilitation Following Upper Extremity Limb Loss. *Curr. Rev. Musculoskelet. Med.* **2020**, *13* (4), 485–493. <https://doi.org/10.1007/s12178-020-09656-6>.
 67. Huinink, L. H. B.; Bouwsema, H.; Plettenburg, D. H.; Van Der Sluis, C. K.; Bongers, R. M. Learning to Use a Body-Powered Prosthesis: Changes in Functionality and Kinematics. *J. Neuro-*

- Engineering Rehabil.* **2016**, 13 (1), 90. <https://doi.org/10.1186/s12984-016-0197-7>.
68. Sharma, A.; Niu, W.; Hunt, C. L.; Levay, G.; Kaliki, R.; Thakor, N. V. Augmented Reality Prosthesis Training Setup for Motor Skill Enhancement. *arXiv* 2019. <https://doi.org/10.48550/ARX-IV.1903.01968>.
 69. Walch, G.; Boileau, P. Prosthetic Adaptability: A New Concept for Shoulder Arthroplasty. *J. Shoulder Elbow Surg.* **1999**, 8 (5), 443–451. [https://doi.org/10.1016/S1058-2746\(99\)90074-5](https://doi.org/10.1016/S1058-2746(99)90074-5).
 70. Raschke, S. U. Limb Prostheses: Industry 1.0 to 4.0: Perspectives on Technological Advances in Prosthetic Care. *Front. Rehabil. Sci.* **2022**, 3, 854404. <https://doi.org/10.3389/fresc.2022.854404>.
 71. Martarello, R. de A. Planned Obsolescence in Public Health Services: The Prosthetic Mafia Case. *Saúde E Soc.* **2022**, 31 (1), e200398. <https://doi.org/10.1590/S0104-1290202200398>.
 72. McLarney, M.; Pezzin, L. E.; McGinley, E. L.; Prosser, L.; Dillingham, T. R. The Prevalence of Lower Limb Loss in Children and Associated Costs of Prosthetic Devices: A National Study of Commercial Insurance Claims. *Prosthet. Orthot. Int.* **2021**, 45 (2), 115–122. <https://doi.org/10.1177/0309364620968645>.
 73. AT2030 Programme. *Product Narrative: Prostheses*, Global Disability Innovation Hub: London, UK, 2020. https://at2030.org/static/at2030_core/outputs/Prostheses_Product_Narrative_a11y_20200827.pdf (accessed 2025-12-08).
 74. Manero, A.; Smith, P.; Sparkman, J.; Dombrowski, M.; Courbin, D.; Kester, A.; Womack, I.; Chi, A. Implementation of 3D Printing Technology in the Field of Prosthetics: Past, Present, and Future. *Int. J. Environ. Res. Public Health* **2019**, 16 (9), 1641. <https://doi.org/10.3390/ijerph16091641>.
 75. Thomas, D. J.; Singh, D. 3D Printing for Developing Patient Specific Cosmetic Prosthetics at the Point of Care. *Int. J. Surg.* **2020**, 80, 241–242. <https://doi.org/10.1016/j.ijsu.2020.04.023>.
 76. Jeong, E. C.; Lee, G. K. Abstract: The Use of a Low-Cost Three-Dimensional Printed Single Channel Myoelectric Interfaced Prosthesis for Transradial Amputees: Preliminary Report. *Plast. Reconstr. Surg. - Glob. Open* **2017**, 5 (9S), 147–148. <https://doi.org/10.1097/01.GOX.0000526377.39346.9a>.
 77. Carro, R. M.; Costales, F. G.; Ortigosa, A. Serious Games for Training Myoelectric Prostheses through Multi-Contact Devices. *Children* **2022**, 9 (3), 423. <https://doi.org/10.3390/children9030423>.
 78. Fietz, K.; Lay, J. Digital Skills in the Global South: Gaps, Needs, and Progress. *GIGA Focus Glob.* **2023**, 2. <https://doi.org/10.57671/GFGL-23022>.
 79. Gilotta, S.; Spada, S.; Ghibaud, L.; Isoardi, M.; Mosso, C. O. Acceptability Beyond Usability: A Manufacturing Case Study. In *Proceedings of the 20th Congress of the International Ergonomics Association (IEA 2018)*; Bagnara, S., Tartaglia, R., Albolino, S., Alexander, T., Fujita, Y., Eds.; Advances in Intelligent Systems and Computing; Springer International Publishing: Cham, 2019; Vol. 824, pp 922–934. https://doi.org/10.1007/978-3-319-96071-5_95.
 80. Össur. *Introduction to i-Limb*. Össur. <https://www.ossur.com/en-ca/prosthetics/upper-limb-training/i-limb> (accessed 2025-12-08).
 81. Hammond, B.; Abu, K. A.; Anyithey-Kokor, D.; Baidoo, P. K.; Leat, M.; Awoonor-Williams, R.; Konadu-Yeboah, D.; Wilson, A. A.; Vormawor, K. K.; Bukari, M. I. S.; Twumasi-Baah Jnr, K.; Amamoo, J.; Opuni, G. Y. F.; Shiako, J. T.; Akomea, G. Determinants of Utilization of Prostheses and Orthoses Following Lower Limb Amputation in Sub-Saharan Africa: A Systematic Review. *J. Orthop. Rep.* **2025**, 4 (1), 100528. <https://doi.org/10.1016/j.jorep.2024.100528>.
 82. Inoue, Y.; Yamanoi, Y.; Kuroda, Y.; Ono, Y.; Shimada, T.; Yabuki, Y.; Yokoi, H. Development of a Waterproof EMG Sensor for Improved Signal Quality by Using Load Balancing. *IEEE Sens. J.* **2025**, 25 (9), 14617–14628. <https://doi.org/10.1109/JSEN.2025.3551507>.
 83. Bolivar, E.; Rezazadeh, S.; Summers, T.; Gregg, R. D. Robust Optimal Design of Energy Efficient Series Elastic Actuators: Application to a Powered Prosthetic Ankle. In *2019 IEEE 16th International Conference on Rehabilitation Robotics (ICORR)*; IEEE: Toronto, ON, Canada, 2019; pp 740–747. <https://doi.org/10.1109/ICORR.2019.8779446>.
 84. Dababneh, S.; Dababneh, N.; Xie, C.; Henchi, H.; Efanov, J. I. Shaping the Future of Upper Extremity Prostheses Through 3D Printing. *Prosthesis* **2025**, 7 (2), 39. <https://doi.org/10.3390/prosthesis7020039>.
 85. Ribeiro, J.; Mota, F.; Cavalcante, T.; Nogueira, I.; Gondim, V.; Albuquerque, V.; Alexandria, A. Analysis of Man-Machine Interfaces in Upper-Limb Prosthesis: A Review. *Robotics* **2019**, 8 (1), 16. <https://doi.org/10.3390/robotics8010016>.
 86. Liu, X.; Zhang, D.; Miao, K.; Guo, Y.; Jiang, X.; Zhang, X.; Jia, F.; Tang, H.; Dai, C. A Review on the Usability, Flexibility, Affinity, and Affordability of Virtual Technology for Rehabilitation Training of Upper Limb Amputees. *Bioengineering* **2023**, 10 (11), 1301. <https://doi.org/10.3390/bioengineering10111301>.
 87. Jones, H.; Dupan, S.; Dyson, M.; Krasoulis, A.; Kenney, L. P. J.; Donovan-Hall, M.; Memarzadeh, K.; Day, S.; Coutinho, M.; Nazarpour, K. Co-Creation and User Perspectives for Upper Limb Prosthetics. *Front. Neurobotics* **2021**, 15, 689717. <https://doi.org/10.3389/fnbot.2021.689717>.
 88. Coapt. Complete Control System Gen2 Handbook (V 5.1). <https://coaptengineering.com/wp-content/uploads/2021/06/Coapt-Gen2-Handbook-v5.1.pdf> (accessed 2026-06-06).
 89. Luchetti, M.; Cutti, A. G.; Verni, G.; Sacchetti, R.; Rossi, N. Impact of Michelangelo Prosthetic Hand: Findings from a Crossover Longitudinal Study. *J. Rehabil. Res. Dev.* **2015**, 52 (5), 605–618. <https://doi.org/10.1682/JRRD.2014.11.0283>.
 90. Fillauer. Hosmer 5 Hook. <https://fillauer.com/product/hosmer-5-hook/> (accessed 2026-06-06).
 91. Amputee Store. Hosmer Prosthetic Model 5X Hook, Stainless Steel. <https://amputeestore.com/products/hosmer-model-5x-prosthetic-hook> (accessed 2026-06-06).
 92. Ottobock. Michelangelo Hand 8E500 Instructions for Use (Qualified Personnel), 2022. [https://res.cloudinary.com/ottobock-se/image/upload/v1/Communication-medias/Technical%20communication%20medias/Instruction%20documents/Manuals/Instructions%20for%20use%20\(qualified%20personnel\)/647G587/647G587-0%3DEN_INT%20-%20Instructions%20for%20use/Web/4817193?_a=BAMCkGiu0](https://res.cloudinary.com/ottobock-se/image/upload/v1/Communication-medias/Technical%20communication%20medias/Instruction%20documents/Manuals/Instructions%20for%20use%20(qualified%20personnel)/647G587/647G587-0%3DEN_INT%20-%20Instructions%20for%20use/Web/4817193?_a=BAMCkGiu0) (accessed 2026-06-06).
 93. Ottobock. AxonSkin Natural. <https://www.ottobock.com/en-us/b2b-product/8S502> (accessed 2026-06-06).
 94. Loth Fabenim. Hosmer 5X, 5XA & 5XTi Hooks. <https://www.lothfabenim.com/en/component/rsfiles/download-file/files?Itemid=4335&path=producten%252FArmprothesen%252F-Haken%252FModel%2B5X%252FEnglish%2B-%2BLoth%2B-Fabenim%2BProduct%2BManual%2BHosmer%2B5X%252C-%2B5XA%2B%2526%2B5XTi%2BHooks.pdf>.

■ Authors

Sheraya Amarasekara, a student at Dubai College, is a student researcher with deep interests in affordable, user-focused prosthetic engineering and the use of genomics for cost-effective, preventative medicine in developing areas. She aspires to improve accessibility via medical policy while innovating as a biomedical engineer in the design and development sector.