

Bionic Arms for Everyone: The Promise of Low-Cost EMG Prosthetics

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Abstract

Prosthetic technology has improved greatly in recent decades, especially with the growth of electromyography, or EMG, control systems. EMG prosthetics use electrical signals from muscles to control artificial limbs, making movement more natural than older body-powered designs. Advanced systems such as the DEKA LUKE Arm and the Ottobock bebionic hand show how modern prosthetics can offer multiple grips, wrist motion, and more precise control. However, these systems are often expensive and difficult to access, especially for users outside well-funded medical systems. At the same time, lower-cost systems such as the Open Bionics Hero Arm and open-source designs connected to e-NABLE and Arduino-based projects are making myoelectric prosthetics more affordable for wider groups of users.

This paper asks whether low-cost EMG prosthetics are feasible alternatives to high-performance devices. Using a qualitative comparative method based on secondary research, it examines four case studies: the Open Bionics Hero Arm, the DEKA LUKE Arm, the Ottobock bebionic hand, and low-cost open-source EMG systems. The comparison focuses on accessibility, control, performance, and real-world usability.

The study finds that low-cost EMG prosthetics clearly improve accessibility. Some low-cost systems begin around a few thousand dollars, while open-source community-made devices may be even cheaper. They can complete basic tasks such as gripping, holding, and carrying light objects. However, they generally provide less precision, fewer advanced control features, and lower durability than high-performance systems. High-end devices perform better, but their price, training demands, and limited availability make them less realistic for many users. Overall, low-cost EMG prosthetics are a practical and important solution for increasing access, even though they do not yet match elite devices in performance. Future progress should focus on narrowing the gap between affordability and functionality.

Keywords: EMG prosthetics, low-cost prosthetic limbs, myoelectric prosthetics, Open Bionics Hero Arm, DEKA LUKE Arm, Ottobock bebionic hand, open-source prosthetics, e-NABLE, Arduino-based prosthetics, prosthetic accessibility, assistive technology, upper-limb prosthetics, affordability in healthcare, prosthetic performance, muscle-signal control, bionic arms, prosthetic usability, prosthetic innovation, medical technology, inclusive design

Introduction

Prosthetic limbs are important because they help people with limb loss regain independence, mobility, and confidence. For many users, prosthetics are not only a medical device. It is a tool that affects school, work, self-image, and daily life. In upper-limb prosthetics, the challenge is especially difficult because the human hand and arm perform many detailed actions, from lifting a bag to buttoning a shirt. Modern prosthetic research tries to restore as much of that function as possible.

One of the biggest advances in this area is the use of electromyography. EMG measures the electrical activity created when muscles contract. In a myoelectric prosthesis, electrodes placed on the user's skin detect muscle signals from the residual limb. The device then translates those signals into movement commands, such as opening or closing a prosthetic hand. Because the control comes from the user's own muscles, myoelectric systems often feel more direct and intuitive than older cable-based systems. EMG has therefore become one of the most widely used control methods in advanced upper-limb prosthetics.

The problem is that better technology often comes with higher cost. Advanced prosthetic systems may include multi-grip hands, rotating wrists, powered elbows, software-based control, and customized fitting. These features can improve function, but they also make devices more expensive and more difficult to maintain. Some advanced prosthetic arms are reported to cost well above \$100,000, while lower-cost commercial systems can start around \$5,999. This wide difference in price shows that prosthetic technology is not only a technical issue. It is also an issue of access and fairness.

This is where low-cost EMG prosthetics become important. A growing number of companies, engineers, and volunteer communities are trying to create devices that are cheaper, lighter, and easier to obtain. Open Bionics markets the Hero Arm as one of the most affordable advanced multi-grip bionic arms, while e-NABLE describes itself as a global volunteer network using 3D printing to create free and low-cost upper-limb devices for underserved communities. These efforts suggest that prosthetic design moves in two directions at once: toward higher performance and toward greater accessibility.

Even so, affordability comes with trade-offs. Low-cost systems may provide basic grip and control, but they may not offer the same precision, strength, range of motion, or long-term durability as high-performance systems. Research also shows that upper-limb prosthetic use depends on more than just engineering. Comfort, simplicity, training, repair, and user satisfaction matter a great deal, and prosthetic abandonment remains a serious issue when users find devices hard to control or not worth the effort of daily use.

That leads to the main research question of this paper: **To what extent are low-cost EMG-based prosthetic systems feasible compared to high-performance systems in terms of accessibility, control, and performance?** The central thesis is that low-cost EMG prosthetics are highly valuable because they improve access and affordability, but they involve real compromises in

control precision, durability, and overall performance when compared with advanced commercial devices. This paper argues that the most important future goal is not simply to build the most advanced prosthetic, but to create devices that more people can realistically use.

Methodology

This study uses a qualitative comparative research method based entirely on secondary sources. No laboratory testing, patient interviews, or direct device trials were conducted. Instead, the paper draws on peer-reviewed journal articles, review papers, official product pages, regulatory documents, health technology reports, and nonprofit community sources. This method is appropriate because it allows comparison across very different prosthetic systems, even without access to the devices themselves.

A literature search was carried out using terms such as “EMG prosthetics,” “surface EMG prosthetic control,” “low-cost myoelectric prosthesis,” “upper limb prosthetic accessibility,” and “body-powered versus myoelectric prostheses.” Sources were selected mainly from recent years so that the discussion would reflect modern devices and current challenges. Foundational older sources were included only when they were necessary for device history or technical background, such as FDA documentation for the DEKA Arm.

The paper focuses on four case studies: the Open Bionics Hero Arm, the DEKA LUKE Arm, the Ottobock bebionic hand, and open-source EMG prosthetic systems such as e-NABLE-linked and Arduino-based designs. These systems were chosen because they represent different points on the prosthetic cost-performance spectrum. The Hero Arm represents an affordable commercial myoelectric system, the LUKE Arm represents a high-performance advanced system, the bebionic hand represents a mid-range clinical option, and open-source systems represent ultra-low-cost innovation.

Each case study was examined using the same criteria: price or affordability, control method, range of motion, ease of use, functional ability in daily tasks, durability, and accessibility. The goal was not to identify a single “best” prosthetic, but to understand how different design priorities affect real-world feasibility. This is especially important because recent health-services research has noted that strong evidence for cost-effectiveness and subgroup benefits of multi-grip myoelectric prostheses is still limited.

Literature Review

Fundamentals of EMG Prosthetics

Surface electromyography has become a key method for prosthetic control because it offers a non-invasive way to detect muscle activity. Electrodes placed on the skin pick up the tiny electrical signals produced when muscles contract. In prosthetic systems, these signals are processed and translated into commands for motors inside a prosthetic hand or arm. This creates

a direct link between the user's intention and the prosthetic movement. Reviews of the field describe EMG-based methods as among the most widely studied and most widely implemented control approaches for upper-limb prostheses.

This matters because upper-limb prosthetics are especially complex. A hand is not just a hook or clamp. It performs gripping, pinching, rotating, stabilizing, and many other fine tasks. EMG control is attractive because it can provide a more natural form of command than purely mechanical systems. Open Bionics, for example, explains that the Hero Arm uses EMG electrodes to detect tiny electrical signals and activate different grips with proportional control. Ottobock describes its bebionic hand as a myoelectric multi-articulating hand with many selectable grips and hand positions.

Even so, EMG control is not simple. A recent review of surface EMG in prosthetic applications explains that signal acquisition can be affected by noise, electrode placement, skin condition, and movement artifacts. A broader engineering review likewise notes that integrating upper-limb prostheses with the human body remains difficult because signal quality, comfort, socket fit, and long-term reliability all affect actual use. In other words, it is possible to design a highly capable prosthetic in theory, but much harder to make one that works smoothly every day.

Types of Prosthetic Systems

Upper-limb prosthetic systems are usually grouped into body-powered, myoelectric, and hybrid designs. Body-powered prostheses use cables and harnesses to convert body motion into hand or hook movement. They are generally durable and often less expensive, but they may offer fewer motion options and can be less natural to control. PM&R KnowledgeNow notes that body-powered prostheses are often more tolerant of wet or dirty environments and may require shorter training periods than myoelectric devices.

Myoelectric prostheses use EMG signals to drive motors. These systems are powered electronically and often provide better cosmetic appearance, more grip patterns, and a more advanced user experience. However, they are also more dependent on batteries, electronics, fitting quality, and training. Health policy summaries note that myoelectric prostheses are powered by electric motors using muscle activity from the remaining limb for control of joint movement.

Hybrid systems combine features of both approaches in an attempt to balance cost, appearance, reliability, and functionality. The wider literature suggests there is still not enough evidence to declare one category universally superior. Instead, the choice depends on user goals, environment, training, maintenance support, and comfort. Recent comparative work on body-powered and myoelectric upper-limb prostheses argues that different design approaches shape how users access function, feedback, and embodiment.

Performance Factors

Several factors are commonly used to judge prosthetic performance. The first is **control accuracy**, meaning how precisely a device responds to user intention. A device that misreads signals or activates the wrong movement can become frustrating or unsafe. The second factor is **responsiveness**, or how quickly the prosthesis reacts once the user contracts a muscle. The third is **range of motion**, including the number of grips, wrist rotation, and other movable joints. Together, these features affect how many tasks a prosthesis can perform in daily life.

The Hero Arm is marketed as offering six easy-to-select grips, 180-degree wrist rotation, and proportional control. The bebionic hand is described as offering 14 grips and hand positions for everyday tasks. The DEKA Arm system, according to FDA documentation, can use multiple channels and modes to control a device with 10 degrees of freedom. These examples show how designers try to increase function by improving the number and quality of available movements.

Yet performance is not just about the device. Training also matters. Clinical and health-services discussions show that myoelectric systems often require time, expert fitting, and repeated adjustment. Research on upper-limb prosthetic evidence has also highlighted the need to measure comfort and usability better, because a technically advanced device may still fail if it is uncomfortable or hard to learn. This is one reason many advanced devices do not automatically lead to higher user satisfaction.

Limitations and Challenges

A major challenge in modern prosthetics is that technology and accessibility do not advance equally. Reviews of upper-limb prosthetics continue to describe high cost as one of the central barriers to access. At the same time, prosthetic abandonment remains a major concern. A review on prosthetic abandonment explains that even though technology has improved, lack of simplicity and a weak sense of natural use can lead people to stop using myoelectric devices in daily life.

Signal quality is another recurring challenge. Surface EMG reviews explain that noise and interference can reduce the reliability of prosthetic control. This is especially relevant for low-cost systems, which may use simpler sensors and processors. Electrode position also matters greatly. A small change in placement can change the signal and therefore the movement command. This means that a prosthesis may not perform the same way every time the user wears it.

Repair and maintenance create another barrier. Low-cost systems may be easier to prototype or replace, especially when 3D-printed, but they may also have weaker durability. High-end systems may use better materials and motors, but they often require specialized maintenance and clinical follow-up. In real life, the best device is not always the one with the highest technical score. It is often the one that a user can actually obtain, learn, repair, and keep wearing.

Research Gap

A clear gap in the literature is that many studies discuss highly advanced systems or technical signal-processing methods without fully comparing them to low-cost alternatives in practical terms. Health technology assessments have reported limited evidence on cost-effectiveness for multi-grip myoelectric upper-limb prostheses, and recent multi-stakeholder work has emphasized the need for better evidence on safety, comfort, and patient subgroups. This means the field still lacks enough real-world comparison between what is technically possible and what is realistically accessible.

There is also limited case-based discussion of affordability versus function. That matters because low-cost devices should not only be judged by whether they are weaker than high-end devices. They should be judged by whether they offer meaningful independence at a price and complexity level that more users can manage. This paper addresses that gap by placing accessibility and performance side by side rather than treating cost as a secondary issue.

Results: Case Studies

Case Study 1: Open Bionics Hero Arm

The Open Bionics Hero Arm is one of the clearest examples of a lower-cost commercial myoelectric prosthesis. Open Bionics describes it as the world's most affordable advanced multi-grip prosthetic arm and says it is available in more than 801 locations across the United States for below-elbow adults and children aged 8 and above. The company also states that the standard Hero Hand weighs 340 grams and can lift up to 8 kilograms, showing that the device tries to balance light weight with practical strength.

In terms of control, the Hero Arm uses EMG signals detected from the residual limb. Open Bionics explains that the device offers six easy-to-select grips, feedback through lights, sounds, and vibration, and proportional control that allows the user to adjust finger speed for delicate tasks. These features are important because they show that a lower-cost system can still provide modern multi-grip functionality rather than only a single open-close movement.

Its biggest strength is accessibility. Open Bionics states that its product range starts from \$5,999, a figure far below the reported price of very advanced devices. The company also openly frames the device around affordability and funding pathways. This does not make the Hero Arm cheap for every user, but it places the device in a much more reachable range than many elite systems.

The Hero Arm's weaknesses are the same qualities that make it affordable. It does not claim the same level of complexity or movement freedom as the most advanced research-grade arms. Although the company presents it as precise and powerful, its design is still meant for accessible daily function rather than maximum possible performance. In this sense, the Hero Arm is best understood as a strong example of how commercial prosthetics can reduce the gap between affordability and usable function, even if they do not remove that gap entirely.

Case Study 2: DEKA LUKE Arm

The DEKA LUKE Arm represents the high-performance end of the spectrum. DARPA stated in 2014 that the DEKA Arm System had gained FDA approval as part of the Revolutionizing Prosthetics program, whose goal was to provide an advanced upper-limb prosthesis with near-natural control mechanisms. FDA documentation shows that the system can accept several different kinds of inputs, including cutaneous myoelectric recording electrodes, and can use multiple channels to manage a device with 10 degrees of freedom.

The LUKE Arm is significant because of how much function it tries to restore. VA sources describe it as the first prosthetic arm capable of performing multiple simultaneous powered movements. The VA also noted that the arm includes preprogrammed grips with varying strength and that its joints can move simultaneously rather than only one at a time. This moves the device closer to the complexity of a natural arm.

The problem is cost and access. Public reporting has placed the LUKE Arm around \$200,000 in some real-world cases, and earlier reporting suggested that its price could be well north of \$100,000. Even if these numbers vary by patient and funding source, the broad picture is clear: the LUKE Arm is expensive enough that it is mainly realistic in specialized medical or veteran-support settings rather than for broad public access.

The LUKE Arm therefore sets the performance benchmark, but it also highlights the accessibility problem. It demonstrates what advanced prosthetic engineering can do, yet it remains too costly and complex to be a universal solution. For this paper's research question, that makes it essential: it proves that high performance exists, but also that high performance alone does not solve the real-world problem of prosthetic access.

Case Study 3: Ottobock bebionic Hand

The Ottobock bebionic hand occupies a middle ground between ultra-affordable and ultra-advanced prosthetics. Ottobock describes it as a multi-articulating myoelectric prosthetic hand that offers 14 different grips and hand positions. The company emphasizes day-to-day tasks such as eating meals, carrying bags, opening doors, and tying shoelaces, which places the device clearly in the category of practical daily-use function.

The bebionic hand is important because it combines multiple grips with a clinical reputation for reliability and usability. It is not described as experimental in the way some advanced prosthetic systems are, nor is it framed primarily as a low-cost alternative. Instead, it appears to target users who need a dependable commercial prosthetic with more advanced capability than simple body-powered devices.

This middle position is useful for comparison. The bebionic hand offers more grip options than the Hero Arm, but it does not appear to reach the full multi-joint complexity of the LUKE Arm. That makes it a useful example of a compromise design: more function than the most basic affordable systems, but less complexity than the most elite devices. In practical terms, such

middle-range systems may fit clinical use well because they balance movement options with more established daily usability.

Its limitation is that it is still likely too expensive for many users, and official pricing is not as openly presented as in the Open Bionics materials. Even without a precise number, its positioning as an advanced commercial multi-articulating hand strongly suggests that it is less accessible than open-source or lower-cost systems. Therefore, the bebionic hand supports the idea that there is a broad spectrum between inexpensive access and top-level performance.

Case Study 4: Open-Source EMG Prosthetics

The open-source category is the clearest example of prosthetic design aimed at accessibility first. e-NABLE describes itself as a global network of around 40,000 volunteers in more than 100 countries who use 3D printing to make free and low-cost upper-limb devices, with an estimated 10,000 to 15,000 recipients. These devices are especially important in underserved communities with limited access to medical care.

Many open-source prosthetic efforts are not full high-performance EMG systems. Some are mechanical, while others use low-cost electronics such as Arduino microcontrollers and basic EMG sensors. A recent study on a low-cost Arduino and 3D-printed myoelectric prototype shows that this area is still active in research and development. A 2024 review of low-cost 3D-printed upper-limb prosthetics also explains that additive manufacturing has helped lower prices and expand design possibilities for partial-hand and transitional devices.

The strength of open-source systems is clear: affordability, customization, educational value, and local innovation. Communities can adapt designs, fabricate parts more cheaply, and experiment quickly. This makes low-cost prosthetics especially important for schools, nonprofits, and underserved regions where traditional prosthetic pathways may not exist.

Their main weaknesses are precision, durability, and standardization. Open-source devices may vary greatly in quality. They often do not have the same regulatory approval, clinical support, material strength, or refined control algorithms as commercial systems. For that reason, open-source EMG prosthetics are better understood as accessibility-driven solutions rather than full replacements for the best commercial systems. Still, they matter enormously because they show that innovation does not have to begin from high price.

Discussion

Cross-Case Analysis

Across all four case studies, the same pattern appears: as performance increases, cost and complexity also tend to increase. The LUKE Arm offers the highest level of advanced function in this comparison, including multiple simultaneous powered movements and many degrees of freedom, but it also sits at the highest cost level. The Hero Arm provides modern multi-grip function and proportional control at a much lower entry price. The bebionic hand sits in the

middle as a clinically practical multi-grip system. Open-source devices prioritize access above all else, but they make the biggest compromises in performance consistency and support.

This comparison suggests that the question is not whether low-cost devices are “as good” as high-end devices in every category. They are not. The more useful question is whether they are good enough to provide meaningful function for a wider population. When looked at this way, low-cost devices perform far better than a simple performance ranking might suggest, because they succeed where many advanced devices fail: they widen access.

Accessibility Versus Performance

Accessibility is the central issue in this paper. A prosthetic system can only improve lives if people can actually get it. The Hero Arm’s lower starting cost and e-NABLE’s volunteer-based free and low-cost devices show how design can move prosthetics closer to wider public use. In contrast, the LUKE Arm shows that technical excellence alone does not guarantee broad impact when prices remain extremely high.

This does not mean performance is unimportant. Users deserve devices that are reliable, safe, comfortable, and useful. A cheap device that breaks quickly or performs badly may not improve life much at all. But the same is true in reverse: a near-perfect device that only a tiny number of users can access cannot be the whole answer. Accessibility and performance must be treated as equal parts of prosthetic success.

Technical Limitations

Several technical problems still affect both low-cost and high-performance EMG systems. Signal noise remains one of the biggest issues. Surface EMG reviews continue to describe motion artifacts, electrical interference, and electrode placement as important challenges. This means that even a well-designed system can behave inconsistently if the signal is unstable.

Training is another limitation. Advanced multi-grip systems often ask users to learn switching methods, timing, and grip selection. Low-cost systems may use simpler controls, but they can still require adaptation and practice. Health-services research has emphasized that patient comfort, socket fit, and usable outcome measures deserve much more attention. In practice, a prosthetic’s daily success depends on the human-device relationship, not only on engineering specifications.

Hardware also matters. Open Bionics promotes the Hero Arm as lightweight and able to lift everyday loads, while the LUKE Arm relies on much more complex architecture. Open-source systems may be fast to build and replace, but they often sacrifice long-term durability and standardization. The result is that low-cost systems are feasible, but their feasibility depends on using them for appropriate goals rather than expecting them to fully match the best research-grade systems.

Future Outlook

The future of EMG prosthetics is likely to depend on better signal interpretation, better materials, and more user-centered design. A 2024 Annual Review article on integrating upper-limb prostheses with the human body emphasizes that the field is moving toward improved interfaces, control methods, and embodiment. Newer reviews also show growing interest in machine learning and more advanced EMG decoding for better prosthetic control.

These advances could help low-cost systems most of all. If software becomes better at interpreting messy signals, then cheaper hardware may still become more functional. If 3D printing materials improve, low-cost prosthetics may become more durable. If open-source communities continue to grow, prosthetic innovation may spread faster beyond major medical centers. The general direction of the field suggests that affordability and performance do not have to remain as far apart as they are now.

Ethical Considerations

There is also an ethical side to this discussion. Assistive technology affects independence, dignity, and social inclusion. When advanced prosthetics remain concentrated in wealthy medical systems, users in poorer communities are left with fewer choices. That makes accessibility more than a design issue. It becomes a fairness issue.

Low-cost prosthetics can help reduce inequality, but only if they remain reliable and respectful of users' needs. It would be wrong to assume that lower-income users should simply accept poor-quality devices. The ethical goal is not just "cheaper prosthetics." It is high-value prosthetics that deliver meaningful function at a lower barrier to entry. This is why balancing cost and quality is the most important challenge in the field.

Conclusion

This paper asked whether low-cost EMG-based prosthetic systems are feasible alternatives to high-performance systems. The answer is yes, but only in a qualified sense. Low-cost systems such as the Hero Arm and open-source EMG-based designs do not fully match advanced devices like the LUKE Arm in precision, control complexity, or likely durability. However, they succeed in a different and extremely important way: they make prosthetic technology available to more people.

The comparison also shows that performance alone is not the best standard for judging a prosthetic system. Accessibility, training needs, comfort, repair, and price all shape whether a device will truly help a user. The bebionic hand shows that middle-range systems can balance practicality and function, while the LUKE Arm shows the outer limit of advanced capability. Together, these case studies reveal that prosthetic design is really about trade-offs, not perfection.

The most important conclusion is that future prosthetic innovation should focus on closing the gap between affordability and performance. Better EMG decoding, stronger materials, smarter software, and user-centered design could help lower-cost devices become more reliable and capable. Until then, low-cost EMG prosthetics should be understood not as inferior copies of elite systems, but as practical tools that serve a major social and medical need. They may not be the most advanced devices in the world, but for many users, they may be the most realistic path to independence.

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