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Designing Better Prosthetics for Use in Rock Climbing and Other Sports

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By

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Abstract

Participation in sports, and rock climbing in particular, is able to offer many benefits to those who have lost or were born without a limb. Depending on the sport the individual wishes to participate in, there remains relatively few to no prosthetics despite the strong desire of amputees to engage in sports. Industrial designers are increasingly needed on teams to bring about change. Their skill set can help create prosthetics that are functional for a given sport, capture that sport's essence, are aesthetically pleasing and comfortable for extended use. Together with engineers and prosthetists, they can find the right materials and methods of manufacturing to produce durable prosthetics at a reasonable price. Missing any one of these factors could lead to a product that's largely ignored which won't be of any help.

Keywords: prosthetics, prosthetic design, rock climbing, climbing, design, industrial design, product design, sports design

Introduction

Rock climbing has seen a surge in popularity over the past few years with new climbing gyms opening all across the country. A large part of its rise in popularity can be attributed to bouldering, a more accessible form of climbing that doesn't need any ropes, clips or harnesses. It's easy to see why with all the benefits that come from climbing. You can move across the country, go to a climbing gym and instantly have a new support group, community and group of friends to talk to. Several studies have shown mental benefits from climbing as it helps with depression and anxiety(Luttenberg et al., 2015). The physical benefit is perhaps the most obvious. It's a highly intensive workout which keeps climbers in shape. Rock climbers have additionally been shown to have a higher strength to body mass ratio than most other athletes(Watts, 2004). Along with the noticeable physical benefits, climbing helps improve proprioception and neuromuscular coordination which helps with conditions such as multiple sclerosis(Steimer & Weissert, 2017). One female climber with cerebral palsy remarked how she noticeable improvement in right hand after climbing. She went from having no grip strength in her right hand to being able to take out the trash on her own(Lee, 2014)

These are all needed attributes for individuals who have lost limbs. There's a sense of isolation when a person loses an arm, leg, hand or really any appendage. They might be blocked from participating in a previous passion or simply find it difficult to find a place they fit in. These factors and others can then lead to depression, an all too common occurrence as nearly a third of individuals who have lost a limb experience where only 6.7% of normal functioning adults do ("Limb Loss Infographic", 2014),(NIMH, 2017). Additionally, after losing a limb a person may find it difficult to move and interact with the world as they were once accustomed. Relearning to walk or write is an equal parts mental and physical challenge. Climbing has the potential to improve upon all these hardships.

Individuals who have lost a limb will be able to immerse themselves in a whole new supportive community. They'll be able to learn to walk with a prosthetic or learn to use their new artificial hands without the stress that might come from a traditional physical therapy environment. In such cases, the patient is so focused on standing and taking a few steps that it's frustrating when results don't immediately show. Climbing can offer a different sort of therapy. Patients can rely more on their arms while on the climbing wall as they learn to move and balance on their replacement legs. The same goes for if a person has lost an arm; they'll overcompensate with their legs and core as they learn to grab and support themselves with their new arms and hands. Then there's the possibility of rope climbing where the rope is there to catch the individual if they find themselves struggling with the replacement limb. Just being at the a climbing gym or at a cliff face with other climbers has an advantage over traditional physical therapy as the community truly wants to see people grow and excel whereas doctors are paid to encourage positivity.

The designer is able to aid in this therapy process through a variety of means. The main method is through producing specialized prosthetics for the climbing environment. When asking an individual at a climbing gym with a

transradial amputation why he doesn't use a prosthetic to climb, he simply responded by saying because there was nothing available. He even said he would be likely to purchase a prosthetic if one were available as there were several disadvantages to climbing without a full limb; the primary one being a greatly reduced wingspan. Despite those disadvantages, he and another woman with a below the knee amputation expressed a lack of confidence when using traditional prosthetics. The prosthetics they typically used in walking and picking things up were regarded as unreliable since they couldn't fully put their weight into the prosthetic and be positive it would hold. There was a lack of feedback and tension that made climbing feel unsafe.

The issue extends past climbing to most other sports, too. The prosthetics that exist to play basketball, go golfing or hit a volleyball seem to be absent of any designer input(the few prosthetics that there actually are). It isn't for a lack of demand, either. The majority of individuals who have lost a limb participate in sports or at the very least want to("Amputee Sport", 2016).

Design Importance

Creating such a sports prosthetic can not be accomplished without incorporating design into the equation. Currently, prosthetists and engineers are the primary driving force behind prosthetics. Engineers develop new technology that allows for complex movement and more precise control over an artificial limb. Prosthetists design and fit prosthetics, often while working directly with patients. They have a background that focuses largely around research and human anatomy and movement.

Engineers and prosthetists both offer a lot when it comes to shaping a prosthetic. Though, they can sometimes lack the human and visual elements that are equally important. It's a real challenge to make something that's aesthetically pleasing, functions in an active environment, and is almost symbiotic with the user. With all the movement that's done in climbing and sports in general, it would be terrible for the prosthetic to chafe a person or be uncomfortable to wear for an extended period. This is where having an industrial designer would be particularly useful as they can focus on the human interaction factor. Other challenges for the designer will be addressing cultural concerns as countries like Haiti stigmatize prosthetics users, especially those whose prosthetics look artificial.

Appearance plays more into prosthetics than is generally realized which is why it is so crucial for designers to work with prosthetists and engineers. Individuals without a limb are already highly self-conscious. If a prosthetic is poorly designed, it will just worsen those image issues. A study has shown that a user's satisfaction with his or her prosthetic is highly related to a positive self body image(Murray, 2002). This highlights how important appearance is when building this prosthetic. A poor design will do more to worsen the problem than solve it. An individual likely won't even use the prosthetic if they don't feel comfortable wearing it. It's not just about making something that's slick or choosing the right color. The prosthetic must embody the sport it's assisting with. That embodiment should lead to a certain level of confidence when climbing a cliff or kicking a soccer ball.

Empowerment is such an important attribute for individuals without limbs which is why it's crucial the design provides this level of self-confidence. It will help alleviate symptoms of depression and lead to these individuals living more active lives. Just the act of climbing is capable of improving self-confidence. That's one of the key reasons for focusing on it so much compared to other sports. Climbing isn't easy, you might not get a problem on the first, second, third or even tenth try. It's work that requires a deal of time without feeling like a constant struggle. Climbing forces people to rely on all of their muscles and skills to overcome the obstacles on a given wall. Because of this you're forced to get incredibly in sync with your body. You need to feel the tension in every muscle, trust your fingers to remain on the climbing hold and feel comfortable high off the ground. When you reach the end of a problem you feel accomplished, like you can overcome anything.

There are other details that will factor into the design. For climbing specifically, there are technical moves such as heel and toe hooks, drop knees and kneebars that the prosthetic's design needs to account for to empower these individuals to climb at the same level as an able-bodied person. Other sports have their own unique moves to account for. These pieces all must blend together and not look like a bunch of mismatched components that have been haphazardly forced together.

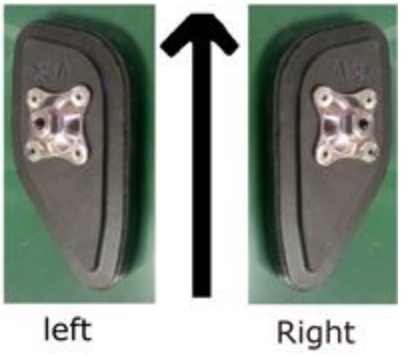
There are more general considerations that will apply to all sports prosthetics. Among them are height adjustment, how the user actually takes the prosthetic on and off and making it so that the design is bilateral instead of needing to produce two different models per appendage. Height adjustment could even end up offering an advantage in certain sports. An extended arm can let an individual grab holds that were previously out of reach when climbing. If someone is missing both legs, the prosthetics don't have to restore them to their previous height but can make an individual as tall or short as they desire.

Prosthetic Overview

Figure 1. El Dorado Z-Axis Climbing Foot, TRS Prosthetics, Retrieved from https://www.trsprosthetics.com/product/climbing/

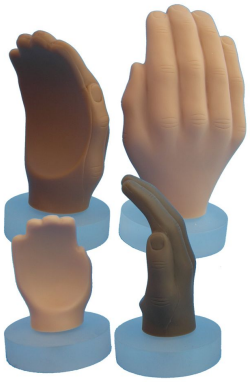
There are two advantages to using this rock climbing foot: it's interchangeable with some other prosthetic feet due to the pyramid adaptor and it has a climbing shoe custom-made for it. It's also bilateral so it can be used on either limb. Past that, it has a poor design as it looks just like a scaled down prosthetic foot. It doesn't take into account the intricacies of climbing; pointed toe is needed for the foot to use all the small cracks, crevices and foot chips that are present on climbing walls. Performing a toe hook would also be close to impossible with this foot. The bilateral, boxy nature of the foot prevents it from being any true help while climbing.

Figure 2. ADK Rock CLimbing Foot, Mountain Orthotic and Prosthetics Services, Retrieved from http://www.mountainoandp.com/adkfoot/



This climbing prosthetic considers some of the technical components of climbing such as the pointed toe. It also has an adaptor to attach to other prosthetics. However, it seems void of any design. It's ugly and wouldn't do anything to instill confidence in the user or even give off the impression that it'smeant to be used for rock climbing.

Free Flex Hand, TRS Prosthetics, Retrieved from https://www.trsprosthetics.com/product/free-flex-hand/



The Free Flex Hand is used in volleyball, soccer and football. While it certainly can do the bare minimum that those sport requires, it's far from aesthetically pleasing. The bend that the hand offers could also prove a determinant in sports like volleyball and football as a strong enough impact from a ball would just fling the hand back instead of stopping the ball in its tracks.

Running Prosthetic, Ottobock, Retrieved from https://www.ottobock.in/prosthetics/lower-limb/solution-overview/running-prosthesis-system/

This prosthetic, as well as the variations of it made by other companies, is one of the few sports prosthetic that fully captures the sport in its design and is actually functional to use. It's a prosthetic that can simulate running through its spring system. Just looking at it makes you think that the user can run as fast if not faster than any runner with two legs.

Materials and Making

Building a sports prosthetic takes lots of time and resources. There are multiple steps from coming up with how it's different from every other prosthetic to building and testing prototypes. They have to support the body's weight in a dynamic environment without failing which will create an immense amount of stress in different planes. These prosthetics also are constantly interacting with the human body which means they not only have to be comfortable, but the materials can't cause skin irritation either. An industrial designer has the potential to aid in every step of this process.

An important consideration when developing a sports prosthetic is that they are generally not covered by insurance as they're not seen as a necessity("Financial Assistance for Prosthetic," 2017). While this can be argued based on the aforementioned benefits, it's currently not able to be changed. This means that the price of the prosthetic will largely decide whether a person uses it as no one wants to spend a fortune just to engage in a sport. A pair of climbing shoes can range from $40 to $200 which would be a reasonable price range for the prosthetic.

One way of keeping costs down is by not reinventing the wheel. The part of the prosthetic that attaches to the leg, known as a suspension system, has a fairly universal socket. They're typically around 30mm in diameter with some variation between models and brands. The designer can work off of this system and design the prosthetic to attach to the suspension system rather than redesign a way of attaching it to the limb. This will also allow a prosthetic user to stick with the suspension system that they're already most familiar and comfortable with. Though, vacuum suspension is recommended when using a sports prosthetic as it provides even pressure over the stump, can be used everyday, and automatically adjust suction to keep the prosthetic firmly attached no matter the activity ("Keeping your leg on," 2017). The same applies to prosthetic feet as many attach through a pyramid socket. These attachment points are also universal, maybe more so than the suspension system sockets. This will keep the same pipe design of the leg but allow a quick, cheap swap out of prosthetic feet.

3D printing offers another means of reducing cost. They're already widely used to create prosthetic arms and hands for individuals. PLA and ABS are cheap, easy to print and can handle basic tasks like picking up lightweight objects. However, these materials would crumble under the entire body's weight. That's where higher end materials can come into play. There are durable resins, metals and even carbon fiber that are capable of being 3D printed. Each of these options has the potential to be more expedient and cheaper than ordering a prosthetic. While ABS and PLA can't be used for final models, they can still be used as cheap materials for rapid prototyping to make sure that the look and feel of a prosthetic is correct.

There is an increasing trend in society for products built with planned obsolescence. Phones are only made to last for a few years before their firmware slows them down. Many common household items are almost intended to break after a few years so that the consumer buys the next model. This practice extends to fashion where clothing is out of season in under a year so that you have to buy the latest trend apparel to fit in. Prosthetics aren't some lifestyle choice or fashion accessory. A person shouldn't have to buy the next model of prosthetic every year or even every other year. Current prosthetics on the market have a variable lifespan. They last anywhere from months to

years depending on level of activity, how often they're cleaned and the overall care of the prosthetic("Prosthetic FAQs", 2015). It should be the goal of the designer to delay this breakdown for as long as possible.

There are a number of ways to extend the life of a sport's prosthetic. One basic method is by making the prosthetic easy to clean. It should be simple to wash the prosthetic after a climbing session. The prosthetic should also be thought of like other sporting equipment where it's only used while participating in that sport. This will prevent the wear and tear that comes with everyday activities. If the design incorporates rubber, that rubber should be replaceable as it is with climbing shoes. By keeping a simple design without joints or anything else complex, the materials will hold up longer and there won't be any small pieces that wear out with time. Incorporating a way to adjust height can extend the prosthetic's lifespan for the adolescent population. Instead of needing to buy a new product every so often, height can simply be adjusted by a centimeter, inch or foot so that it matches the length of the growing body.

Conclusion

The desire to take part in sports overwhelmingly exists within the amputee population. It's a proven means of improving both mental and physical health. While many of these people already compete in sports, they are generally at a disadvantage compared to able-bodied individuals. Designers are able to make a real difference in this field. They can create prosthetics that empower individuals both in the sense that they can play on the same level as anyone else along with increasing their self-confidence and give them the feeling that they can climb over any wall put before them. Only an industrial designer's state of mind and skill set working in tandem with the abilities and knowledge of engineers and prosthetists can create such a product.

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