3D Printed Stroke Rehabilitation Exoskeleton Design
(Technical Paper)

Accessibility and Fairness: Prosthetics in Sporting Competition
(STS Paper)

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By
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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

Stroke is among the top three most common causes of death and is among the main causes of acquired adult disability in most countries. Full or partial loss of motor function in muscles is one of the most common impairments caused by stroke, and as a result most medical treatment is based around rehabilitation (Langhorne et al., 2011). Rehabilitation is unique to every patient and must be tailored to their specific needs, but a common form of rehabilitation is exercise, in order to strengthen muscles that have been weakened. There is strong evidence that exercise has "positive physical and psychosocial effects on patients after strokes" (Ochieze et al., n.d.). Robot-assisted stroke rehabilitation is a method of treatment focused on effectively leveraging the motor capabilities of patients and allow them to individually perform exercise and motor-relearning (Ochieze et al., n.d.). However, such equipment can be expensive and difficult to acquire outside of a medical facility, and there is a need for a less expensive, more easily accessible alternative. The final technical deliverable will be a low-cost, 3D printed upper-limb exoskeleton for stroke rehabilitation that will allow for patients to have access to equipment to perform specific exercises to assist in rehabilitation, without the high costs associated with state-of-the-art equipment.

Unlike robotics for stroke rehabilitation, which are specifically designed and tailored for patients to recover motor function that has been lost, prosthetics are designed to allow patients who have experience loss of one or multiple limbs to restore normal function and allow for participation in daily activities that one otherwise may not have been able to do. Prosthetics may also allow patients to participate and compete in athletic sporting competitions, such as Oscar Pistorius, a double amputee who attempted and ultimately failed to qualify for the 2008 Summer Olympics against able-bodied runners thanks to the assistance of prosthetic legs (Bidlack, 2009).

It is a common practice to create a separate level of competition specifically for those competing who require the use of prosthetics or some other form of assistance due to disability, such as the Paralympics, but as prosthetics become increasingly advanced, it will be more common that athletes using prosthetics will be capable of competing in general athletic competitions, like Pistorius. While these developments will allow for sporting competitions to increase accessibility and remove barriers that may prevent those with disabilities from competing, legislation and social pressure from those who prioritize the fairness and integrity of these sporting competitions must also be considered. Research must be done on whether or not prosthetics could give athletes an unfair advantage in athletic competition, and if that is the case, what should be done in order to maintain fairness in these competitions, and the final research deliverable will be a research paper investigating and analyzing these topics.

Technical Topic

Robotics for stroke rehabilitation can play a crucial role in the recovery of motor function in muscles that have been impaired as a result of a stroke. However, much of the technology surrounding robot-assisted stroke rehabilitation is unaffordable for many patients, and as such a financial barrier exists between the patient and treatment that could be crucial in their recovery. Commercially available robotics for stroke rehabilitation can cost anywhere from hundreds to several thousand dollars, and use of rehabilitation devices through a facility for physical therapy with a doctor typically comes with expensive medical bills, although the resulting financial toll on the patient may be dependent on their health insurance. This project will focus on the design and creation of a low-cost alternative to currently available commercial products, specifically focusing on the creation of an upper-limb exoskeleton that will assist in repeatable exercises in order to improve motor functionality and relearning after a stroke.

In order to create a fully-functioning exoskeleton that can assist in the performing of exercises for stroke rehabilitation, multiple design aspects must be considered. First, signals from the patients' muscles must be analyzed in order to determine which movements the exoskeleton needs to perform and assist. Signal data collection can be done using electromyography (EMG) signals, which when analyzed can determine the intention of the patients' movements (Lei, 2019). Another useful sensor is an Internal Measurement Unit (IMU) sensor, which detects the movement and rotation of the sensor and can be used to more precisely control the motors and the movement of the exoskeleton (Ganesan et al., 2015). These sensors are used to provide the necessary data to determine the intention of the user, the exoskeleton will use motors or actuators to assist or perform the desired movement (González-Mendoza et al., 2022). All of these components will have to seamlessly work together in order for a usable final product.

By collaborating with other mechanical engineering students at the University of Virginia including Madison DePierro, Caleb Jung, Abby Kong, Samantha Nicholson, Carly Thurman, and Joel Val, we aim to create a more affordable upper-limb exoskeleton that will allow patients to easily perform specific exercises that will assist in stroke rehabilitation. This project will take place over the course of an entire academic year and will require multiple stages of progress. After initial targets have been specified for metrics such as degrees of freedom for arm motion, or range of motion, designs for components will be created using 3D modeling software, and the code that will run the motors and actuators in the design will be created. The code and designs for this project is intended to be open-source, and therefore accessible to everyone. After a prototype of our stroke rehabilitation exoskeleton has been created, testing will need to be done in order to determine the level of performance of our design. If needed, improvements will be made through multiple iterations of the design, with the goal of a final deliverable that is capable

of assisting in stroke rehabilitation exercises, while still remaining affordable for patients who wish to use the product for commercial use in home.

STS Topic

Sports and other athletic competitions provide a healthy way for people to compete against each other and emphasize effort, teamwork, and leadership. Evidence shows that both physical and cognitive functions are improved by physical exercise, and sports provide a fun and enjoyable way for people of all ages to participate (Garcia-Falgueras, 2015). Since physical activity is at the forefront of a large number of sports, those who have disabilities such as loss-of-limbs have traditionally been barred from participating in these events. The alternative is typically competing in separate and distinct categories of sporting competitions, such as the Paralympics, where participants are still able to reap the benefits of competing in sports (Du Plessis & Berteanu, 2020). However, prosthetics have made large developments in recent history in allowing patients to restore normal function to areas where a loss-of-limb has occurred. Studies show that movement of amputees aided with modern prosthetics is very similar to that of control groups (Jarvis et al., 2021). In fact, the technology in the field of prosthetics has developed so greatly that when athletes using prosthetics were interviewed, participants were satisfied with the ability of prosthetic feet to allow for sporting competition (Poonsiri et al., 2020). With the evolution of modern prosthetics to the point where in several athletic competitions it is possible for amputees to compete with the use of prosthetics, the question arises: should athletes using prosthetic devices be allowed to compete in sporting competitions alongside able-bodied athletes?

In order to answer this research question, I will be analyzing the sources used through the lens of the social construction of technology (SCOT). The social construction of technology is a

common STS framework that analyzes technology as a consequence of social movements, asserting that technology is created by society and is a social construct, not the other way around (Klein & Kleinman, 2002). In order to use this framework within the context of the research question posed above, I will view the development of both athletic competitions and the field of prosthetics as driven by society and the wants and needs of relevant social groups, such as athletes, people with disabilities, medical professionals, and sports viewers. One critique of the framework is that the SCOT views society as composed of relevant groups, and places equal importance on all relevant social groups which is flawed in its nature, according to Pinch (1996). With that critique in mind, this research question must also be analyzed not only to determine the social groups involved in the evolution of these technologies, but how these social groups interact with each other and which are most influential.

Research Question and Methods

Research Question: Should athletes using prosthetic devices be allowed to compete in sporting competitions alongside able-bodied athletes?

In order to further investigate this research question, I will use the research methodology of discourse analysis. Discourse analysis is the method of interpreting data gathered through literature reviews, interviews, or other events that generate dialogue. This method is similar to documentary research but allows for non-traditional sources such as social media posts (Seabrook, 2022). In order to first research the evolution of prosthetics and their effectiveness in allowing for patients to participate in sports and other athletic competitions, I will analyze literature reviews, scholarly articles, and research journals detailing the current state of prosthetics technology and their applications. I will also use scholarly analysis in order to come to a conclusion on whether or not the field of prosthetics has advanced to the point where

athletes using them could not only compete with those who are able-bodied and do not require prosthetics, but if they gain a competitive advantage from the use of these technologies. Finally, I will need to use other resources including sports journal articles, interviews, and social media discourse to analyze how society supports or opposes the use of prosthetics in sporting competition based on the principles of accessibility, fairness, and integrity of the competitions. Since the investigation of the research question above requires the use of literature reviews, scholarly articles, and research journals, as well as the use of less traditional resources within scholarly research such as social media discourse, the use of discourse analysis is important to fully and completely investigate the topic.

Conclusion

This prospectus document overviews two significant projects designed to address issues within the field of biomechanics. The first deliverable is a technical capstone project that aims to design and create a low-cost wearable exoskeleton for stroke rehabilitation. Strokes are a deadly event that can cause muscle impairment in adults after their occurrence, and current studies suggest that rehabilitation focused on exercise of the affected muscles can be very beneficial as patients recover. However, the technology surrounding robot-assisted stroke rehabilitation is expensive and can lead to patients being excluded from using these machines due to financial barriers. This technical project intends to create a more affordable alternative using 3D printed, open-source designs which will be capable of assisting patients in repeatable exercises for stroke rehabilitation.

The second deliverable is a research paper that analyses the use of prosthetics in sporting competitions. Prosthetics have evolved significantly over time and now allow for some patients to participate in athletic events despite a loss-of-limb. As a result, athletic competitions can allow

for far more accessibility than ever before. An issue may arise within the social context of sports regarding the fairness and integrity of these competitions if it is deemed that prosthetics may provide an unfair advantage to those athletes. This research will analyze the field of prosthetics, whether or not they may give athletes an advantage in sporting competition, and what potential solutions exist to allow for sports to be more accessible while also maintaining fairness.

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