Title: Biomechanics and Kung Fu: Bringing Traditional Martial Arts and Prosthetics Together

Advisor Information

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Statement of Purpose. Martial Arts are a fantastic way to meet exercise goals and develop confidence in self-defense. And they should be accessible to all individuals including people with lower limb amputations. Lower limb prosthetics can be improved to make martial arts more accessible to those who use them. My goal is to experiment with prosthetics to discover how they can be improved to make martial arts more accessible.

Throughout the project, I hope to identify limitations in prosthetics and consider how they would affect someone learning martial arts (specifically, Southern Shaolin Kung Fu). I also plan to use my internship as an opportunity to work with prosthetics and find out if I wish to pursue prosthetic studies in higher education.

Background. Biology has always been the science I have been the most excited about. The complexity of biological functions and their uniqueness is extremely interesting. As I learned more and more about how various biological systems worked I started to see similarities and differences in my everyday life. I keep trying to think about how biology affects things that seem “ordinary” but are incredibly complex. From wondering how the bark beetles affect pine trees to shining a light through my fingers to see the bones within; I’ve considered some form of biological field as a place to start my higher educational studies and hopefully a career. It seems only natural that I’d start looking at how Biology affects kung fu.

I have studied and practiced Southern Shaolin Kung Fu for the past seven years. Through this time, I have noticed the incredible flexibility that one could develop, especially the way joints could become strong enough to hold seemingly impossible martial stances. Recently I have encountered multiple athletes that have lower limb prosthetics who shared their success stories online. I’ve seen hikers, runners, and weightlifters, but have

not seen many people doing martial arts. It seems logical there may be challenges to practicing kung fu while having a limb with atypical joint mobility. I knew for my senior project I wanted to apply the field of biology to kung fu and then I had an idea. How could prosthetics be improved to make Southern Shaolin Kung Fu more accessible to those who use them?

II. Prior Research. Prostheses are any artificial body parts used to assist someone with a disability. When it comes to prosthetic legs, there are two types, transtibial and transfemoral. Transtibial prosthetics are used when the patient has had a below-the-knee amputation and consist of a socket, a pylon (the "shin" of the prosthetic), and a foot. Transfemoral prosthetics are used when the patient has had an above-the-knee amputation, consisting of a socket, a knee joint, a pylon, and a foot (Rajťúková et al, 2014). The prosthetic typically attaches to the patient's residual limb via suction to a sleeve worn on the limb. The suction method is widely used due to its strength and simplicity. Both transfemoral and transfibular prosthetics have been used since the European Middle Ages and technology has continued to improve. As technology continues to advance so do the options for prosthetics. Modern prosthetics range from simple immobile limbs, mechanical limbs, to active limbs (Asif et al, 2021). Mechanical prosthetics use clever joints to create a system that only moves when the correct weight/pressure is applied. Active prosthetics are prosthetics that use some form of algorithms, motors, sensors, etc. to assist in the movement of the prosthesis. The advancement of active prosthetics is increasing rapidly, with various methods of motion being investigated. As active prosthetics are studied more they will become more efficient and thus more common (Windrich et al, 2016). Unfortunately, active prosthetics are currently heavier and more expensive than their simple mechanical counterparts.

There is significant and overwhelming evidence that exercise is extremely beneficial to human health, with recent studies showing that whole-body exercise can assist in the prevention of 40 different health conditions (Ruesegger et al, 2023). As exercise becomes an increasing part of medicine those with lower limb amputations (LLA) must also be able to get sufficient exercise. Beyond the general benefits of extended lifespan and better health that exercise offers to everyone, those with LLA have more to gain. Amputees who feel confident with their ability to exercise have higher ratings of their overall body image (Tatar, 2010). Because of the close link between body image and psychosocial health, LLA amputees need to participate in physical exercise for their mental health along with their physical health. Unfortunately, very few do. A study in the Netherlands found that only 32-39% of lower limb amputees participate in sports. The study explores multiple variables that could act as barriers to sports for those with LLA. Among the top barriers are the physical, mental, and social blockages. While mental barriers can be

weakened by actual participation in a sport, physical barriers require specific modifications to prostheses to overcome, or at least make manageable.

Current technologies such as running blades can help those with LLA run more effectively by mimicking the spring force of a biological leg better (Laferrier et al, 2010). Running blades consist of a curved carbon fiber “blade” that stores energy when the user steps and allows them to spring forward similar to how a biological leg functions. Running blades are not a perfect fit for every sport, but they can significantly reduce the amount of energy needed by prosthetic users to run at the same level as non-amputees. Unfortunately, running blades have been challenged as giving those with LLA an unfair advantage in sports competitions, leading to competitions like the Olympics blocking lower limb prosthetic users from using running blades to compete. Those who claim running blades give an unfair advantage use the concept of the blade storing energy as evidence for the supposed advantage. More spring energy with each step would theoretically mean people with running blades could run faster. However, after more study, it was found that amputees (specifically bilateral amputees, those who have one amputation on each leg) did not gain any advantage due to their running blades and were still slowed by their requirement for a prosthetic (Beck et al, 2022).

Significance. Currently, there are no prosthetics that can mimic a biological leg perfectly. Continued advancements like running blades and active prostheses certainly increase the quality of movement and thus the lives of people who rely on them, there is still plenty of room to improve (Asif et al, 2021). Investigating possible prosthetic improvement for Southern Shaolin Kung Fu is valuable not only because it would help kung fu become more accessible to amputees with a lower limb prosthetic, but it would also greatly improve quality of life. Kung fu can improve strength, balance, and flexibility, which are all things humans need for basic function. Unfortunately, people with lower limb amputations tend to struggle with balance, something that is made difficult purely by the mechanics of having a prosthetic foot. Newer advantages such as bimodal foot designs can increase the patient’s ability to balance (Hansen et al, 2013). With increased balance comes increased confidence and an overall improvement in well-being. I hope to learn ways to improve people's well-being using a combination of teaching martial arts and making it physically easier for prosthetic users to walk, run, or one day demonstrate incredible Shaolin flying kicks. I hope to learn ethical ways to do research and gather information that can be applied to help people who need it. I firmly believe kung fu is for everyone, and I want everyone to feel confident when they try to fly.

Methodology

A. **Selection of Participants.** To analyze the differences between a biological leg's function and a prosthetic leg's function, we measure participant's ankle mobility to compare with the mobility of a prosthetic limb. To select participants, we will ask 3-5 Black Belt students at Sacred Mountain Fighting and Healing Arts to participate. If they show interest they will be given informed consent forms detailing how and what data will be collected, what will remain confidential (things like name and age), and showing the assumption of risk. If they still are interested and consent to the terms they will be able to participate in the study.
B. **Data Collection on Biological Leg.** In this stage, we will focus on ankle mobility during three of the major stances in Southern Shaolin Kung Fu, bow stance, cat stance, and twisted stance. Due to stances being asymmetrical, we will collect the front and back ankle range of motion. To measure the range of ankle mobility, participants will be asked to hold one of the three stances while we measure the comparative angle at which the ankle is bent. Data will be organized to compare what range of motion was required for each stance.
C. **Data Comparison to Prosthetic Leg.** Next comes the collection of data for the Prosthetic legs, in this stage, we will take similar measurements to the biological leg by manually manipulating the ankle joint to simulate the stances. We will take note of the extent of mobility that prosthetic legs demonstrate for comparison.
D. **Comparison and Hypotheses.** With the data collected, we will begin the actual comparison process. By looking at the measured range of motion for a biological ankle joint and comparing it to the possible limits of the prosthetic ankle joint. Then, using the compared data, we will consider what methods could be used to increase ankle joint mobility (softer foot, more flexible ankle, bifurcated foot plate, etc.).
E. **Testing Solutions.** If time and money allow, I would also like to build the theorized improved prosthetic as a proof of concept. We would build a prosthetic that takes into consideration the changes hypothesized to increase the ability to hold martial stances. Then repeat the trials with the modified prosthetic and evaluate any changes in performance.

Problems. I may not have access to various prosthetics for testing ankle mobility. In this case, I would reach out to other prosthetists and ask for permission to borrow the prosthetic I would need for the project. The 3D Printer may break or otherwise be non-functional for the creation of the hypothetical prosthetic, if this occurs we will troubleshoot the problems. If the errors continue I will simply use a diagram of my proposed solution prosthetic for my final product, instead of a completed prosthetic. When it comes to the human component of the project, participants are skilled in kung fu and are aware of proper warm-up and stretching to ensure stance work is practiced safely. If one member becomes injured or otherwise unable to participate, I will attempt to find a

replacement participant and follow the proper procedures for them to participate. If no replacement can be found, then the project will continue with slightly less data.

Budget. There is the cost of time for my external advisors, internal advisors, participants, and myself. There is a possibility of building a prosthetic while taking into account the information I gathered, at which point there would be a cost to Next Step Prosthetics to allow me to use their 3D printer and other supplies. This cost is covered by my external advisor who already gave permission for me to possibly build a prosthetic with him at the end of the project.

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