Thesis Project Portfolio

Designing and Testing a Novel Custom 3D-Modeled Post-Operative Knee Brace

(Technical Report)

The Equitable Design of Post-Operative Knee Rehabilitation Protocol

(STS Research Paper)

An Undergraduate Thesis

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Sociotechnical Synthesis

Combined, total knee arthroplasty (TKA) and ACL reconstruction surgeries constitute nearly one million surgeries performed annually in the U.S. alone (Hewett et al., 2010). With the demand for total knee replacement surgeries projected to grow by 673 percent to nearly 3.5 million operations by 2030, the need to properly rehabilitate patients after their operation is of high importance (Kurtz et al., 2007). Typical rehabilitation works in stages, beginning with completely restricted movement and employing multiple braces throughout the recovery process that each allow different ranges of motion. Our capstone project was aimed at developing a novel post-operative brace design that acts as a 'one-stop-shop' for recovery. This brace will be custom-fit to the patient and will have an adjustable range of motion throughout recovery and adaptable force redistribution intensity at the joint to unload forces on the tibia. Patients who have undergone TKA can lose up to 62% of their quadriceps strength due to the atrophy, and some patients have permanent physiological limitations to their knee's range of motion, a condition known as knee flexion contracture (KFC), as a result of the long-term immobilization of the joint (Anania et al., 2013; Mizner et al., 2005). Our brace hopes to address the shortcomings of current technology by allowing the patient to exercise their mobility at all stages with assistance from the brace, and foster better recovery of the knee joint following operation.

Post-operative rehabilitation plans are designed to ensure a full and proper recovery for the patient. However, not all rehabilitation plans should look alike, depending on many factors related to the patient and their health. It is important to design a plan for each patient while keeping their age, physical ability, gender, and any other lifestyle or health factors in mind. A recovery plan tailored to the specific needs of the individual patient will make it easier on the physician to accurately monitor progress, while also making it easier on the patient both

physically and mentally as they feel that they are making that progress. The STS framework that I will be using to investigate my topic is outlined by Steve Woolgar in his 1990 article "Configuring the user: the case of usability trials" (Woolgar, 1990). The use of this framework will aid me in my analysis to answer this question: How do the current standards of treatment and rehabilitation protocol for patients undergoing knee surgery contribute to an inequitable recovery process for patients of different ages, abilities, and genders, and why is this so when it produces undesirable outcomes for certain individuals? Investigating this question is foundational to the equitable design of the recommendations physicians and physical therapists provide to patients post-operatively.

Looking back on this year's work, I found great value in working on both of these projects simultaneously. The Capstone project allowed me to research patient needs, the current market, and use skills I have gained throughout the BME curriculum to fully develop a novel functional knee brace that will aid in improving patient outcomes and quality of life. In a similar vein, my STS Research Paper allowed me to better understand the disparities in the rehabilitation protocol and uncover who is currently underserved. If I hadn't been working on the STS Research Paper at this time, I wouldn't have been able to equitably design this brace to best serve all targeted patient demographics, and without the Capstone project I wouldn't have had the background knowledge to truly understand the foundations of the recovery process for such procedures. Working on these two projects has helped me to hone in on many skills that I have learned over the past four years– at times those skills felt very technical-focused or ethics-focused depending on which project I was working on– but looking back they have been intertwined all along to make me a better engineer.

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