Anatomical Impacts of Custom 3D Printed Lower-Limb Orthoses

How do Socioeconomic Disparities Affect People With Prosthetics and Implants

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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

Knee osteoarthritis poses a significant health challenge, impacting the quality of life for millions worldwide. Current interventions, including knee braces, aim to alleviate pain and improve function. However, a nuanced understanding of their impact on gait dynamics and muscle activity is crucial for optimizing therapeutic outcomes. Among these interventions, knee braces emerge as a promising avenue for managing symptoms and enhancing mobility. However, a comprehensive understanding of how these braces influence the intricate mechanics of gait, muscular activation, and bone health is crucial for refining their efficacy and ensuring optimal patient outcomes. That is why I am working under Icarus Medical to create an IRB-approved protocol and OpenSim model to investigate exactly how knee braces and KAFOs (Knee ankle-foot orthoses) improve patient gait and muscle activation. The analysis will be conducted by quantifying gait dynamics utilizing MAMP cameras and Vicon's system for precise gait analysis, focusing on knee valgus angle, knee adduction moment (KAM), and multi-planar knee flexion-extension. EMG data will be collected to investigate electric potentials in key muscles (quadriceps, hamstrings, tibialis anterior, calves, and gluteus maximus) during various phases of gait. Surveys of volunteer pain levels throughout the procedure will be conducted to gain a subjective baseline understanding of how much pain volunteers are in and how well the 3D-designed knee braces alleviate that pain. Lastly, OpenSim modeling will be conducted to compare the OpenSim database joint angle estimates to our experimental data. The social dimension of my topic is the economic implications implants and other prosthetics have on people of different socioeconomic classes. As new devices, technologies, and remedies are created, the price of those aids has increased. This creates a wealth gap for those in need of medical prosthetics but are unable to either receive them, conduct maintenance on them or have them replaced as needed. If humans advance to the point that certain implantation is a requirement to be a functioning member of society this will only affect low-income demographics. I will investigate the previous history to see if as technology improves, the disparities also increase. The investigation of how socioeconomic classes affect a user's experience with prosthetics and implants is very important to create a more inclusive atmosphere in healthcare. It highlights the importance of ensuring that all individuals have the same opportunities for good health, regardless of their socioeconomic status. Healthcare disparities can lead to higher healthcare costs. Preventing and managing diseases at earlier stages, rather than addressing them in advanced and costly stages, can result in cost savings for healthcare systems. Reducing socioeconomic gaps in healthcare can lead to improved public health outcomes. When people have equal access to healthcare services, preventive measures, and treatment, it benefits the entire population by reducing the prevalence of diseases and promoting overall well-being. Not to mention, with an increased representation of other demographics services and healthcare products can better serve a larger population of patients, resulting in improved outcomes for all users. Therefore, this thesis will perform a quantitative analysis of knee braces and KAFOs while determining how socioeconomic factors users of such braces and other assistive devices.

Anatomical Impacts of Custom 3D Printed Lower-Limb Orthoses

In order to aid Icarus Medical in determining how effective their 3D-printed knee braces and knee-ankle-foot orthos are in alleviating knee pain and improving patient gait, various methods of data collection are needed. These methods include walking dynamics analysis(gait) using motion capture cameras and electromyography sensors to investigate the joint angle and muscles of involvement when walking. The motion analysis will be collected by using sensors that track position over time along with pressure plates to determine the force each foot is exerting during each motion of a walking cycle. That motion data will then be into Vicon's analysis system to extract the position data of the joint we fixed the marker to. The locations of the markers will include the knee, hip, and ankle. This will allow us to have a better understanding of how the knee moves in a 3-dimensional space relative to the midline of the legs. Next EMG sensors will be placed on the quadriceps, hamstrings, glutes, shin muscles, and calf muscles. These are the main contributing muscles involved in walking and running. Along with the motion capture data, this will allow us to see how the muscles interact with each other to compensate for a weak knee joint with and without a knee-supporting brace when the knee reaches various angles of rotation about the midline of the leg. Once experimental motion data is collected, it will be compared with a constructed OpenSim model. OpenSim allows users to build models of musculoskeletal structures with any combination of rigid bodies, simple and complex joints, constraints, and many other components. It also houses an extensive musculoskeletal model library that can be accessed. We will create a model that is similar to the movements performed in the experiments, such as walking, leg extensions at the knee, and other plyometric stances to see muscle compensation when trying to maintain balance. This will allow us to determine how close our experimental results are to what the model simulates. Our experiments will aim to have at least 6 volunteers with preexisting or current ailments that result in lowered knee flexibility and functionality. Ailments include osteoarthritis, Charcot-Marie-Tooth (CMT) Disease, Cerebral Palsy, Multiple Sclerosis (MS), Stroke/Cerebrovascular Accident (CVA), and Muscular Dystrophy. Analysis of how Icarus Medical's knee braces and KAFOs affect the knee joint will allow them to have more comprehensive data and information to provide to their clients increasing their quality of life and satisfaction with the Icarus product.

How do Socioeconomic Disparities Affect People With Prosthetics and Implants

The social dimension of my topic is the economic implications implants and other prosthetics have on people of different socioeconomic classes how this could affect future generations and the regulation of such equipment. As new devices, technologies, and remedies are created, the price of those aids is increased. If humans advance to the point that certain implantation is a requirement to be a functioning member of society this will only affect low-income demographics. Implantation of a device or prosthetic can be potentially life-changing. If the difference between a high quality of life versus a poor one post operation is a matter of status and money this should be investigated because the healthcare market should be looking to reduce such disparities. Lifetime estimates for directly associated costs range from $345,000 to nearly $600,000, depending on how often the prosthesis is replaced and the age at the time of amputation. The direct and indirect health costs as a result of amputation could easily exceed $1 million for an individual before accounting for any loss of wages or salary due to an inability to work. These are just estimates of currently available treatment plans[5]. The costs of new treatment plans will surely increase leaving the average client unable to afford the full care plan they need. This is important because understanding this phenomenon will be important to make sure that any inequalities that may arise with new technologies are mitigated to prevent a greater wealth gap.

The experimental test would be to conduct interviews on people who have received prosthetics and ask them how receiving them has affected their quality of life and if they were of a higher socioeconomic status would it improve? Data collection will consist of semi-structured interviews. The interviews will be designed to elicit narratives about their experiences with prosthetic/implant care, including access, challenges, and maintenance. An interview Guide will be developed with open-ended questions that address the following areas: Socioeconomic background and status, Access to healthcare services, Financial aspects of care, Quality of care received, Challenges and barriers faced, Coping strategies, and support systems. Audio recordings of all interviews will be documented for accuracy and future analysis. However, the anonymity of each volunteer will be secure for their safety. The interview data will be analyzed and transcribed using thematic analysis. Recurring themes, patterns, and narratives will be identified that are related to the impact of socioeconomic status on prosthetic/implant care. Participants would be provided with the opportunity to review and validate the findings to ensure the accuracy of the data and interpretations. An analysis of preexisting research into how socioeconomic status plays a role in the care of prosthetics and implants will also be performed. This will provide validity to the interviews that will be conducted because interpreting qualitative data from interviews is a nuanced and iterative process. It involves looking beyond the surface and striving to understand the rich and varied experiences of participants in the context of socioeconomic disparities in healthcare access and maintenance.

Conclusion

Knee braces and KAFOs offer potential solutions for managing knee osteoarthritis, but understanding their technical impact on gait dynamics and muscle activity is crucial for optimizing their effectiveness. Through an innovative research approach, Icarus Medical is conducting an in-depth analysis using state-of-the-art technology. Cutting-edge tools such as MAMP cameras and Vicon systems enable precise gait analysis, focusing on key parameters like knee valgus angle and knee adduction moment. Additionally, EMG data collection provides insights into muscle activation during various gait phases. OpenSim modeling is employed to compare experimental data with established joint angle estimates. This technical investigation aims to uncover the intricate mechanics behind knee braces and KAFOs, offering a comprehensive understanding of how these devices impact gait dynamics and muscle activation. Such insights can lead to improved design and customization, ultimately enhancing patient outcomes and the efficacy of these interventions. The economic implications of prosthetic devices impact individuals across socioeconomic classes. As technology advances, the cost of these aids rises, creating disparities in access and maintenance. Investigating how socioeconomic status influences users' experiences with prosthetics is essential for equitable healthcare. Addressing healthcare disparities can reduce costs, improve public health, and enhance healthcare product representation, resulting in better outcomes for all users. This thesis aims to examine how socioeconomic factors impact the utilization of knee braces and KAFOs, shedding light on the economic barriers that certain individuals face in accessing and maintaining these critical devices. By exploring the relationship between socioeconomic status and the ability to obtain and sustain prosthetic aids, we can work towards a more inclusive and fair healthcare system that provides equal opportunities for good health regardless of one's economic background. I expect to see that those with lower income will have higher rate of prosthetic usage, lower ability to maintain prosthetics, and lower access to resources.

Citation

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