Adapted Trike

Chloe M. Goff[1], Victoria A. Green[1], Samantha M. Underhill[1], Cole R. Sullivan[1], Melanie G. Watson Ph.D.[1]

[1]Bock Department of Biomedical Engineering, Trine University, Angola, Indiana 46703

Trine University
Biomedical Engineering

Introduction and Motivation

Multiple sclerosis (MS) is a disease that affects the brain and spinal cord, pieces that make up the central nervous system (CNS) [1]. Antigens of the CNS selectively recruit T and B cells causing the inflammatory effects of MS. The immune system attacks the myelin sheath covering nerve fibers, resulting in inflammation, causing nerve cell destruction [1]. MS effects nearly 2.8 million people worldwide and nearly 1 million people in the U.S. [2]. Diagnosis of multiple sclerosis are shown in **Table 1**.

***Table 1**: Diagnosis of Multiple Sclerosis.*

RRMS	SPMS	PPMS
• First neurological symptoms • Subacute clinical events that reduce over time	• Clinical episodes or disability is irreversible	• Symptoms progress • Patient does not experience remission

The customer is Nichole Reynolds and was diagnosed with RRMS when she was 22 years old, working at Parkview Hospital as a registered nurse (RN). Initial symptoms were vision deficiencies and numbness in her right arm. 10 years ago, Niki's right hip extensor began to weaken and limit her range of movement, limiting her ability to exercise. Today she experiences numbness in her right arm and leg, wears an AFO, and walks with a cane to assist her right side. Niki wanted to ride a tricycle again in order to exercise and improve her quality of life.

Customer Needs

The customer's needs were determined after a meeting at Five Lakes Coffee in Auburn, Indiana. The customer's old trike was too heavy for her to propel the trike forward, thus requiring a lightweight frame. The new trike frame is made of carbon steel as opposed to pure steel. Due to the customer's lack of physical activity for the past decade, she will likely experience fatigue, so an electric assist was incorporated for safety. The customer uses a cane in her day-to-day life, so a cane holder was attached to the basket for easy access. Due to the customer's weak right hip extensor, gait lab experiments were conducted to determine proper modifications. Summary of the customer's needs is shown in **Figure 1**.

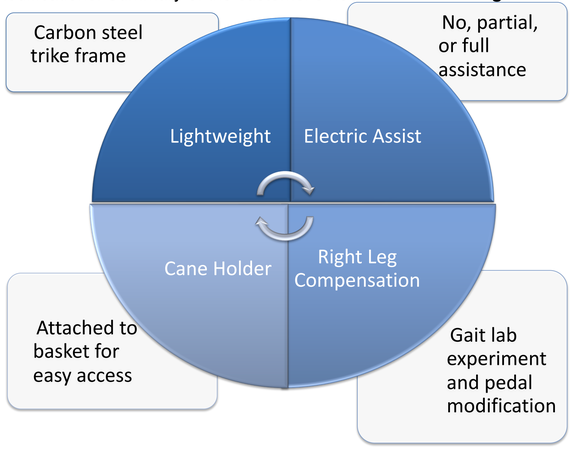

***Figure 1**: Visual representation of the customer's needs.*

Methods

Niki participated in three different experiments in the Biomedical Engineering Department's Gait Lab to analyze the forces applied by both of her legs, as well as the range of motion in both of her legs. This data would be applied to the crank length adjustment. The three experiments were static balance standing, walking, and sit to stand trials. Specific anthropometric measurements including height, weight, leg length, and widths of joints was collected. 16 reflective markers were placed at locations from the waist to toes to collect data. The Vicon Nexus software created lower body pipelines to view and process the trials. MATLAB was utilized to obtain the results. Graphs for the ground reaction forces and knee angles were produced. Ground reaction forces are measured based on the subject's interactions with the ground.

***Figure 2**: Niki performing a walking trial during the gait lab experiment.*

Validation of the project was accomplished through performing a repeatable survey for each customer visit. The survey consisted of questions regarding all aspects of the trike that were being altered to fit the customer's needs. The customer completed three visits and six surveys.

Various CAD drawings were completed throughout the course of this project. **Figure 3** shows a CAD drawing for the trike frame with the basket included and was used to perform FEA in the Fall. **Figure 4** shows the CAD of a sample crank length adjustment. **Figure 5** shows the final pedal modification which includes a wall to keep the customer's foot on the pedal and an angle was applied to accommodate for the customer's laterally rotated kneecaps.

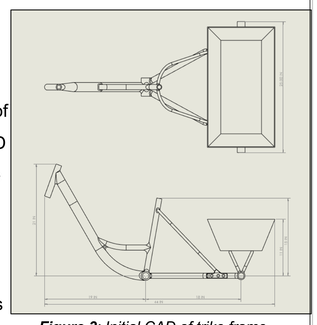

***Figure 3**: Initial CAD of trike frame for modeling and FEA purposes.*

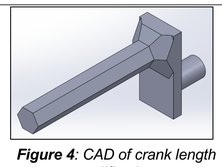

***Figure 4**: CAD of crank length modification.*

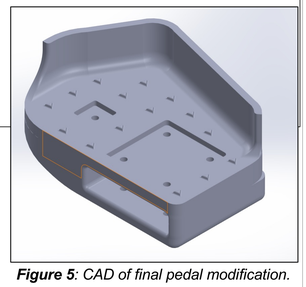

***Figure 5**: CAD of final pedal modification.*

Results

From the ground reaction forces, it was determined the right leg provides less force than the left leg on average, which was expected with Niki's weak right hip extensor. On average, during walking and standing gait lab trials, the right knee angle was smaller than the left, prohibiting Niki's range of motion. Sit to stand yielded mixed results for the knee angles due to the design of the trials. The results from each trial are shown in **Figure 6**.

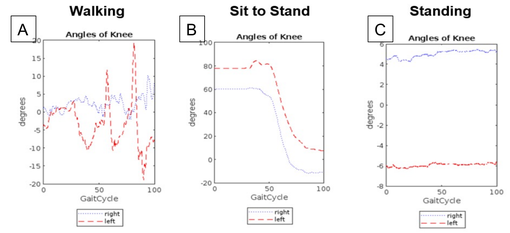

***Figure 6**: Knee angle results from a walking [A], sit to stand [B], and standing trial [C].*

Range of motion results were deemed more important to the final design. Ground reaction forces can be improved through building endurance and strength. Range of motion cannot be improved as easily. Therefore, the pedal modifications were the new pedal in **Figure 5**. Niki also expressed she did not like the crank length adjustment during testing.

The customer's visits consisted of six sessions of testing the trike by getting on and riding it, followed by filling out a survey with various questions regarding her experience on the trike. The most notable survey questions were chosen to be displayed in **Table 2**.

***Table 2**: Survey results from all customer visits with the following scale: 1=Strongly Disagree, 2=Disagree, 3=Neutral, 4=Agree, and 5=Strongly Agree.*

Statement	Response					
	4/6	4/20	4/20	4/27	4/27	4/27
I am having a good day.	5	5	5	4	4	5
I am comfortable pedaling on the trike.	4	4	5	5	4	5
I can get on and off the trike with little to no difficulty.	4	4	5	4	4	4
The locking mechanism makes it easier to get on the trike.	N/A	2	N/A	N/A	N/A	N/A
My cane fits tightly in the cane holder.	5	5	5	4	5	5
The seats locking mechanism makes it difficult to get on the seat.	N/A	4	N/A	N/A	N/A	N/A
My cane is in the way of pedaling.	1	1	1	1	1	1
The seat does not move while riding the trike.	5	4	5	5	1	5
My right foot stays on the pedal while pedaling.	4	3	4	N/A	5	5
I feel safe getting on and off the trike seat.	5	4	5	4	4	5
My right foot slips off the pedal while pedaling.	3	3	2	N/A	1	1
I have difficulty pedaling with my right leg.	2	5	4	N/A	2	2

Conclusions

- Gait lab testing confirmed strength discrepancies between the customer's legs
- Multiple surveys were completed to validate customer's needs were met
- CAD drawings were completed for FEA, crank adjustments, and pedal modifications
- Customer rode a trike for the first time in over a decade

***Figure 7**: Customer riding the trike with no electrical assist.*

Future Applications

There should be more affordable options available to those with disabilities to be to participate in activities they enjoy. Maintaining physical activity can benefit an individual's physical and mental health [3]. The equipment can be tailored to certain restrictions, but then customized for the individual. Modifications are determined by testing and individual preference. Although testing gives concise results, the individual's option needs to be the most important design factor.

Literature Cited

[1] S. Amor and H. V. Noort, Multiple Sclerosis. Cary: Oxford University Press, 2012.

[2] "Updated atlas of MS shows over 2.8 million people worldwide have multiple sclerosis -- with nearly 1," *National Multiple Sclerosis Society*, 11-Sep-2020. [Online]. Available: https://www.nationalmssociety.org/About-the-Society/News/Updated-Atlas-of-MS-Shows-Over-2-8-million-People. [Accessed: 11-Apr-2023].

[3] "Multiple Sclerosis and Exercise: Why MS Patients Should Stay Active," *Penn Medicine*, 01-May-2017. [Online]. Available: https://www.pennmedicine.org/updates/blogs/neuroscience-blog/2017/may/multiple-sclerosis-and-exercise. [Accessed: 12-Apr-2023].

Acknowledgements

Contacts

Chloe Goff: cmgoff20@my.trine.edu
Victoria Green: vgreen19@my.trine.edu
Samantha Underhill: smunderhill19@my.trine.edu
Cole Sullivan: crsullivan16@my.trine.edu