June 12th, 2023

Dr. Michael Hegedus
School of Engineering Science
Simon Fraser University
Burnaby, BC, V5A 1S6

Subject: ENSC 405W/440 Letter of Transmittal for Requirements Specification

Dear Dr. Hegedus,

Roll Technology has prepared this requirement specifications document for ENSC 405W/440, outlining the specifications for Chairable. Our aim is to create a modular product that acts as an attachment to convert a generic office chair into a motorized one.

Chairable is a modular office chair attachment specifically designed with a spherical wheel mechanism to facilitate powered movement. After attachment, the user can sit and move the chair in any direction around using simple controls at low speeds. This would allow the user to enhance their workplace environment by making it more fun and accessible

The document includes our overall project scope and the requirements from the initial stages to the final stages of the product. The general system requirements and more specific requirements like the mechanical, software and electrical are listed. Additionally, it also consists of the safety and sustainability requirements our products will be conforming to.

Should you have any questions or require additional information please do not hesitate to contact our Chief Communication Officer, Divyam Sharma, via email (divyams@sfu.ca) or via phone (+1 236-512 4989). We will be more than happy to address any concerns or provide any clarification you may require.

Sincerely,

Kaj Grant-Mathiasen
Chief Executive Officer
Roll Technology

ENCLOSED: Requirements Specification for Chairable

Company #13

Requirements Specification:
Chairable

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Abstract

This document outlines the requirement specifications of Chairable, developed by Roll Technology. Chairable is a modular attachment for office chairs designed to enable powered movement using a spherical wheel design. We will provide a general overview of the preliminary requirement specifications and the justification where appropriate for our choices.

Chairable has several subsystems which comprise the final product: a general microcontroller system which translates user input into control signals, a mechanical system to drive a dual motor spherical wheel design, and an electrical circuit to regulate battery charging and power distribution. Chairable will also involve basic software systems to regulate operation and safety features. A large focus will be made to implement this unique mechanical design.

This design specification will describe the technical implementation of Chairable including the requirements for each feature. These requirements will be classified by category and further documented by stage, from proof of concept, to engineering prototype, and finally to production version. This document will also provide details on the final proof-of-concept device which will be demonstrated in a poster presentation.

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Glossary

The following table describes several terms mentioned throughout the document.

Term	Definition
Microcontroller	A compact computer on an integrated circuit which is dedicated to perform a specific function
Omni-Directional	The ability to move in both forward and lateral movements simultaneously
PWM	Pulse Width Modulation
I/O	Input/Output (ex. usb port)

1 Introduction

With a mission to reimagine the traditional office space, Roll Technology developed Chairable, which will offer a fun and accessible solution to enhancing workplace environments.

Chairable is an innovative attachment that seamlessly integrates an advanced battery powered spherical wheel system, a strategically-placed footstand, and an intuitive user interface. Chairable aims to motorize the office chair, enabling users to control the chair's movement through the user interface instead of relying on navigating with pushing movements. This motorized add-on is unique through its combination of modularity and compactness, offering a cost-effective and practical solution to enhance the capabilities of existing office chairs. Additionally, the incorporation of a unique omni wheel design ensures exceptional maneuverability, especially within confined office spaces. This combination of features makes Chairable truly unparalleled in the market.

1.1 Background

Repetitive interruptions requiring individuals to stand up and retrieve items can cause frustration and physical strain, particularly for those with joint/back pain or a dislike for frequent disruptions to their seated work. The concept of a mobile chair, introduced by one of the founders' father, sparked inspiration to create a solution that eliminates the need for repetitive standing and sitting.

Moreover, sitting at a desk for extended periods can become monotonous. Individuals consistently seek innovative and captivating additions to their office spaces or desks to infuse excitement and enhance their work experience. From incorporating vibrant plants and stylish desk accessories to exploring the realm of desk gadgets, people constantly strive to make their workstations more engaging [1]. Chairable aims to inject a sense of enjoyment and liven up the daily routine of sitting at a desk, offering a delightful and dynamic element to combat tedious desk-work.

Additionally, individuals with limited mobility encounter a multitude of challenges in the office environment [2][3][4]. Individuals using a wheelchair in the office reported discomfort while performing various activities [5]. It is worth noting that approximately 288,000 Canadians rely on some form of mobile aid, emphasizing the widespread need for accessible solutions [6]. Unlike traditional mobility aids like power chairs, which are often expensive and unsuitable for various office environments due to their size, limited maneuverability, and inability to fit under desks, Chairable directly challenges these constraints and provides a simple alternative.

1.2 Further Applications

The innovative omni-wheel design developed by Roll Technology exhibits significant potential for widespread integration within diverse industries. These sectors include manufacturing and warehousing, where the technology can optimize material handling processes and enable efficient automation. Moreover, in logistics and distribution, the omni-wheel's capacity for agile movement empowers robots and autonomous vehicles to navigate with enhanced dexterity. Furthermore, the system enables meticulous and prompt transportation within healthcare environments. The exceptional versatility of the omni-wheel design presents an extensive range of possibilities for implementation across various sectors that seek heightened mobility and improved maneuverability.

1.3 Scope

The following document provides an overview of the functional requirements expected from our team at Roll Technology for Chairable. It encompasses both the overall functional requirements for the entire system and the specific requirement specifications for each component. Additionally, these requirements are classified according to their development stage, which includes proof of concept, prototype, and finished product.

1.4 Intended Audience

This specification document regarding Chairable is intended for Dr. Mike Hegedus and his teaching assistant, Yalda Faroutan. The potential clients of this product are individuals that use the standard wheeled desk chair within an office environment. Specifically, workers with mobility issues who would like to have an easier time maneuvering around with a motorized office chair.

1.5 Requirement Classification

The requirements and constraints in this document are organized according to the following convention:

Req/Con {Section}.{Requirement/Constraint Number} {Stage of Development}

Encoding	Stage of Development
A	Proof-of-concept
B	Engineering Prototype
C	Production Version

Table 1 - Development stage Encoding

2 System Overview

Chairable is an omni-wheel based attachment designed for office chairs. This section will outline the main design concepts Roll Technologies plans to incorporate into the initial design and aid as a high-level background for justification of the requirements needed for each aspect of the design.

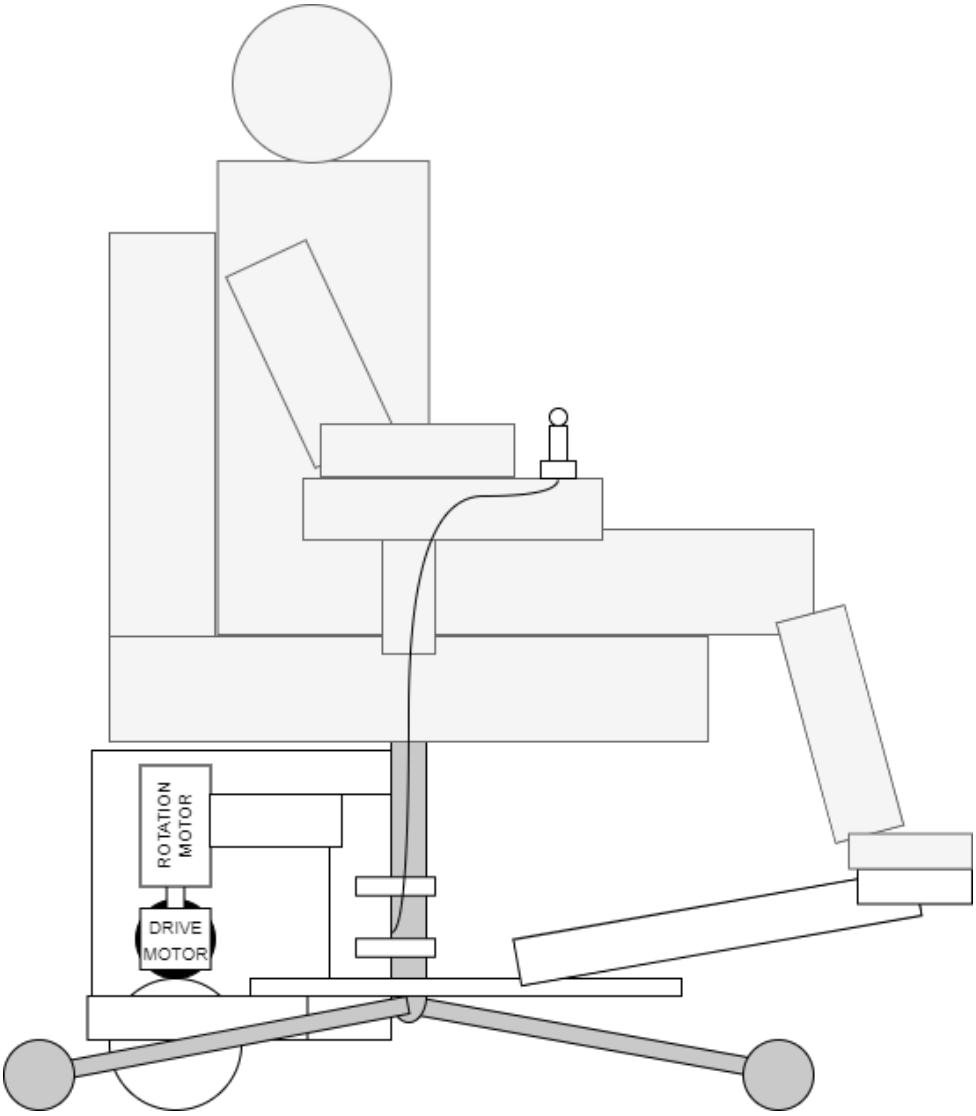

Figure 1 - High level concept design

Figure 1 shows a concept design of Chairable. This device is compact enough to fit under a standard office chair and relies on the chair's 5 star shaped leg pattern as a foundation and clamps onto the central chair column to provide support and structural integrity. A footrest is also incorporated into the design allowing the user to comfortably rest their feet which would otherwise be obstructing the path of movement. A dual motor design is utilized to enable both powered driving with the main drive motor and lateral movement with the rotational motor.

One of the key advantages of this system is its user-friendly nature, requiring minimal training or skill to operate and set up. The attachment can be easily affixed to various office chair models without the need for extensive modifications or technical expertise. The intuitive controls and straightforward installation process ensure that users can quickly adapt to the device and begin using it effectively. This low training requirement eliminates barriers and enables individuals with limited mobility to effortlessly incorporate the attachment into their daily office routines.

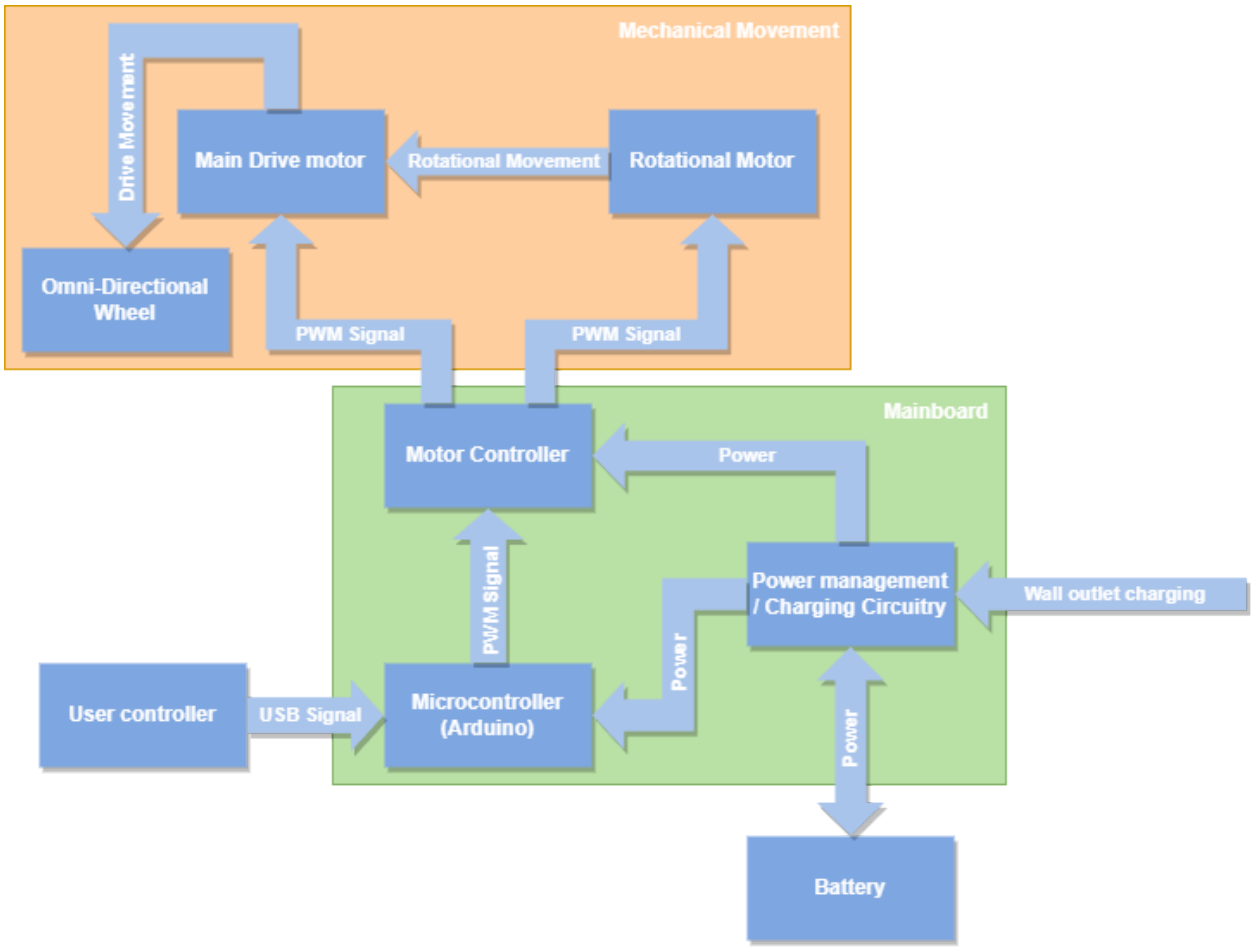

Figure 2 - Chairable System Block Diagram

Figure 4 demonstrates the high level system design of Chairable. The Omni-Directional wheel is powered by the main drive motor. This motor performs the main chair movement and will be large enough to move the combined weight of the chair and user. The main drive motor is rotated by a smaller rotational motor. This will allow for turning and lateral movement. Both motors are controlled via a motor controller which will regulate the power and adjust the speed based on the microcontroller signal and power management circuitry. The user controller will be external and attach to the microcontroller with a usb cable or other similar I/O port. A custom power management and charging circuit will regulate the power delivery to each component of our system and allow the product's internal battery to be re-charged via a common wall outlet.

Chairable is an innovative attachment that transforms the way we engage and navigate within office environments, offering a compact, modular, and cost-effective solution. By prioritizing user experience and adopting a straightforward design, it not only enhances the appeal of the office space but also enhances accessibility and mobility. Our aim is to revolutionize the conventional office setup by reimagining how we interact and move, making it an engaging and inclusive experience for all.

3 General Requirements

The following section details the requirements for each subsystem. Each requirement will be classified by the aforementioned ID scheme and justification is provided where appropriate.

3.1 System Requirements

This section introduces the general requirements of the device, with a primary focus on its overall functionality and non-electrical components. Electrical and software-related aspects will be elaborated on separately. The general requirements emphasize what the system is expected to accomplish as a whole including the integrations between each subsystem. Key considerations include its intended purpose, usability, versatility, reliability, and compatibility. By addressing these system requirements comprehensively, the device will provide a robust and satisfying user experience.

Requirement ID	Requirement Description
Req 3.1.1 A	The system will consist of a battery-powered wheel system, a footstand, and a user interface.
Req 3.1.2 A	The device should have the ability to be controlled using a handheld or hand-operated controller.
Req 3.1.3 B	The device must be able to move an office chair at slow walking speed.
Req 3.1.4 B	The device must be able to travel in every direction.
Req 3.1.5 B	The device should be able to handle the weight of an office chair and large adult.
Req 3.1.6 B	The user interface should be intuitive and easy to understand.
Req 3.1.7 B	Wheel(s) should maintain traction on a variety of floor surfaces, ensuring stability and maneuverability.
Req 3.1.8 B	Wheel(s) should not leave marks on the floor surface.

Req 3.1.9 B	The footstand must have sufficient size to accommodate an adult's feet comfortably.
Req 3.1.10 B	The device should exhibit sufficient durability to withstand collisions with obstacles without sustaining significant damage.
Req 3.1.11 B	The device should be equipped with an on/off button that ensures the device is powered off and prevents accidental usage.
Req 3.1.12 C	The device should not restrict regular use of the office chair when not actively engaged.
Req 3.1.13 C	The device must be compact enough to fit under an office chair.
Req 3.1.14 B	The device should be easy to attach to most existing office chairs.
Req 3.1.15 C	The footstand should provide the flexibility to be easily retracted or moved according to user preference, while also allowing for convenient storage when not in use.

Table 2 - System Requirements

3.2 Mechanical Requirements

The following section details the mechanical requirements of the device. This includes how the device will attach to the chair, the motor system, and the overall physical design of the product. These requirements ensure the device can be attached to a variety of office chairs while still remaining structurally sound and ensuring efficient movement.

Requirement ID	Requirement Description
Req 3.2.1 A	The clamp around the center chair column must possess sufficient strength to ensure stability even when the chair is in motion.
Req 3.2.2 A	The driving motor wheel should have a textured surface to ensure consistent traction on the spherical wheel.
Req 3.2.3 B	The motor system should be assembled in a manner that ensures consistent and full range of motion while maintaining structural integrity.
Req 3.2.4 C	There should be a mechanism to adjust the clamp height with respect to the chair seat and chair leg clearance.

Table 3 - Mechanical Requirements

3.3 Electrical Requirements

In the following section, the electrical requirements of the device are explored. These requirements include various aspects related to power management and delivery. By addressing these electrical considerations, we can ensure optimal performance and user satisfaction while utilizing the device.

Requirement ID	Requirement Description
Req 3.3.1 A	The device should be rechargeable.
Req 3.3.2 A	Voltage and current levels of the individual components should be within safe limits to prevent any damage to other parts of the system.
Req 3.3.3 B	The device should feature a battery with a long-lasting capacity, capable of providing a full day's usage without the need for recharging, even under moderate or occasional use.
Req 3.3.4 B	The controller(s) should be powered by the battery on the device.
Req 3.3.5 B	The wires must not tangle or break when the motor spins to prevent malfunction.

Table 4 - Electrical Requirements

3.4 Software Requirements

In this section, we will discuss the software requirements related to motor control, communication, and stability. These requirements involve user-input control, as well as the ability to handle input and output. By addressing these software requirements, we can optimize the device's control capabilities and ensure stable motor operations.

Requirement ID	Requirement Description
Req 3.4.1 A	Software must be able to adjust and control the motor speed based on user input.
Req 3.4.2 A	Software must be able to control the direction of the motor based on user input.
Req 3.4.3 A	Software should be able to rotate the motor clockwise and counterclockwise based on user input
Req 3.4.4 A	Software on the microcontroller must be able to communicate with the motor controller.
Req 3.4.5 A	Software must be able to receive feedback from the motor controller.

Req 3.4.6 B	Software should have feedback to stabilize motor rotation to ensure smooth movement.

Table 5 - Software Requirements

3.5 Constraints

Chairable faces several limitations that influence the design considerations of the product. The focus on affordability necessitates finding the right balance between material durability and cost, which impacts the material selection. Additionally, the modular design enables long-term usability, even with chair replacements over time. However, modularity and the constraints of size and portability impose limitations on motor selection. Motors must provide sufficient strength within the given budget while also considering their size and weight. Similarly, battery weight and size becomes a consideration due to the device's portability requirements. In addition, to keep the required expertise of customers low, the device should be designed for easy attachment, ensuring a seamless installation process. Moreover, user control should be kept relatively simple to keep the barrier to entry low, allowing users of varying technical abilities to easily operate the device. By carefully assessing these limitations, Chairable can prioritize modularity, portability, and ease of setup and takedown, while maintaining an affordable and user-friendly experience.

Constraint ID	Requirement Description
Con 3.5.1 C	Entire device should cost less than $800.
Con 3.5.2 C	The device should be modular to allow attachment to a variety of chairs.
Con 3.5.3 C	The device should be easy to attach to keep required expertise of customers low.
Con 3.5.4 C	User control should be kept relatively simple to reduce the learning curve.
Con 3.5.5 C	Total device weight should be under 20kg for users with compromised strength/mobility.

Table 6 - Constraints

4 Safety and Sustainability

To ensure Chairable can be operated safely with low risk to the user, we have imposed several requirements to the design. There are significant mechanical components that have the potential to cause harm to a user given improper design or use. Additionally several electrical components such as the large battery have sufficient capacity to cause electrical damage or harm. Our team has imposed several safety requirements to mitigate any potential for mechanical or electrical harm.

In the previous section on constraints, we highlighted the importance of maximizing the long-term usability of our device. Furthermore, we will place a high priority on incorporating sustainable practices into our design, such as utilizing easily replaceable parts and implementing a design that aligns with this objective.

Requirement ID	Requirement Description
Req 4.1 B	The device should have an emergency shutoff if it reaches an unsafe temperature or speed.
Req 4.2 B	The device should feature easily replaceable parts, enabling convenient part replacement and maintenance when needed.
Req 4.3 B	The device's electronics should be enclosed and electrically shielded to prevent electric shock.
Req 4.4 B	Mechanical components should be fully enclosed within a casing to prevent crushing of fingers and catching of clothes.
Req 4.5 C	The device will have no significant protrusions to ensure user safety.
Req 4.6 C	All wiring on devices must be organized and routed efficiently to aid part replacement and avoid tangling.

Table 7 - Safety and Sustainability Requirements

6 Conclusion

Roll Technology's Chairable is a groundbreaking solution that re-imagines the traditional office space by revolutionizing office chairs. This motorized add-on seamlessly integrates advanced battery powered wheel technology, a strategically-placed footstand, and an intuitive user interface, offering a cost-effective and practical enhancement to existing office chairs. Chairable's unique omni-wheel design ensures exceptional maneuverability and a whole new way to enjoy your office. This omni-wheel design holds immense potential in various industries, revolutionizing processes in manufacturing, warehousing, logistics, distribution, and healthcare.

This document outlines the requirements that define the scope and overall functionalities of Chairable, focusing on the user's perspective. Extensive attention has been given to the general system, mechanical, electrical, and software subsystems to encompass all crucial aspects of the Chairable design. Furthermore, safety, sustainability, and other general constraints have been carefully outlined to guarantee that Chairable remains a product that offers both enjoyment and long-term safety for years after its purchase.

7 Appendix

The Proof-of-Concept deliverables which will be presented during the August poster presentation consist of:

1. Functional motor system with a spherical wheel demonstrating both driving and rotational movement
2. Chair movement controlled by user interacting directly with a hand controller
3. Proof of Concept battery charging system

8 References

[1]S. L. SCHEIBERG, “Emotions on Display,” American Behavioral Scientist, vol. 33, no. 3, pp. 330–338, Jan. 1990, doi: https://doi.org/10.1177/0002764290033003007.

[2] D. Wilson‐Kovacs, M. K. Ryan, S. A. Haslam, and A. Rabinovich, “‘Just because you can get a wheelchair in the building doesn’t necessarily mean that you can still participate’: barriers to the career advancement of disabled professionals,” Disability & Society, vol. 23, no. 7, pp. 705–717, Dec. 2008, doi: https://doi.org/10.1080/09687590802469198.

[3] N. Welage and K. P. Y. Liu, “Wheelchair accessibility of public buildings: a review of the literature,” Disability and Rehabilitation: Assistive Technology, vol. 6, no. 1, pp. 1–9, Jan. 2011, doi: https://doi.org/10.3109/17483107.2010.522680.

[4]C. Bellemare, M. Goussé, G. Lacroix, and S. Marchand, “Physical Disability, Discrimination, and Public Subsidies : Evidence from a Field Experiment Controlling for Workplace Accessibility,” 2019 [Online]. Available: https://www.fss.ulaval.ca/sites/fss.ulaval.ca/files/fss/economique/professeurs/Physical_Disability_and_Labor_Market_Discrimination.pdf

[5] B. Troy, R. Cooper, _Rode Aso, and T. Grey, “Department of Veterans Affairs analysis of work postures of manual wheelchair users in the office environment,” Journal of Rehabilitation Research and Development, vol. 34, no. 2, pp. 151–161, 1997 [Online]. Available: https://www.rehab.research.va.gov/jour/97/34/2/pdf/troy.pdf

[6] E. M. Smith, E. M. Giesbrecht, W. B. Mortenson, and W. C. Miller, “Prevalence of Wheelchair and Scooter Use Among Community-Dwelling Canadians,” Physical Therapy, vol. 96, no. 8, pp. 1135–1142, Aug. 2016, doi: https://doi.org/10.2522/ptj.20150574.