A PEER MENTORSHIP TO ENHANCE ACTIVE LIFESTYLES AND COMMUNITY INTEGRATION IN PEOPLE WITH SPINAL CORD INJURY: I WHEEL

by

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The following individuals certify that they have read, and recommend to the Faculty of Graduate and Postdoctoral Studies for acceptance, a thesis/dissertation entitled:

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Abstract

Wheelchair maintenance is an important factor in wheelchair mobility. Currently, there is no standardized training resource available to teach wheelchair users about the maintenance or set-up of their manual wheelchairs. **Purpose**: The purpose of this feasibility research was to assess the feasibility of conducting an experimental study to evaluate the wheelchair maintenance training program. **Method**: The research program had two main phases. Phase 1 included the development of learning materials, evaluation forms and tests. We performed reliability tests on the 3-cone test and wheelchair maintenance knowledge test and report them in chapter two and three. Phase 2 entailed a feasibility study. In this study, we conducted a wheelchair maintenance workshop to train the mentors (n=5) and then assigned each mentor three mentees (n =15). Each mentor conducted a one-on-one peer-session with each mentee and each mentee completed assigned tests and questionnaires during three assessment visits (baseline, and 2 and 4 weeks after their peer session). Feasibility outcomes were evaluated, and all mentees completed an exit survey at the end of the wheelchair maintenance training program. **Results**: The 3-cone test and the wheelchair maintenance knowledge test are reliable (ICC >0.9) to use in clinical research. In feasibility study for wheelchair maintenance training, the process outcome (recruitment rate: mentor 71%, mentee 25%), resource outcome (retention rate (>90%), adherence (>90%), fidelity (>80%), completion rate (>90%) and training satisfaction (>90%) and preliminary evaluation outcomes were achieved. Scheduling (management outcome) was challenging and we were not able to meet the goal projected for this outcome, however we were able to complete all the sessions. **Conclusion**: The 3-cone test and the wheelchair maintenance knowledge test appear to be useful and reliable to be used in the clinical setting. Summary and descriptive results from the feasibility study were sufficient to justify conducting a subsequent randomized controlled trial.

We hope to replicate the findings of wheelchair maintenance training by demonstrating the change in mechanical efficacy of wheelchair and the increased knowledge about wheelchair maintenance in the future. This evidence could then be used to support changes in teaching and knowledge improvement in wheelchair maintenance.

Lay Summary

A training program was developed to evaluate the knowledge about manual wheelchair maintenance and teach manual wheelchair users to perform maintenance on their wheelchair. The program was based on peer-led training and the goal was to find the best model to bring knowledge from research to community. Results from this program will be used to develop a larger training program for manual wheelchair users.

Preface

The research for this dissertation was coordinated at the International Collaboration On Repair Discoveries, Vancouver, British Columbia. Masters candidate, Mehdi Eshraghi developed the project in consultation with his supervisory committee who included supervisors (Drs. Bonita Sawatzky and Ben Mortenson) and committee member (Dr. Linda Li). Ethics were obtained from the Behavioral Research Ethics Board at the University of British Columbia (Certificate #: H15-00046) and from Vancouver Coastal Health Research Institute (Certificate #: V15-00046). The material of this thesis has not been previously published. However, we are preparing manuscript for publications.

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List of Abbreviations

Confidence Interval (CI)

Intra-class Correlation Coefficient (ICC)

Minimum Detectable Change (MDC)

Randomized Control Trial (RCT)

Standard Error of Measurement (SEM)

World Health Organization (WHO)

Glossary

Assistive technology: Any equipment designed and developed to improve the performance capabilities of the individuals with impairment (McCreadie & Tinker, 2005).

Feasibility study: Smaller scale research performed before the larger scale study to find out if the main study can be done (National Institute for health Research, 2015).

Intra-rater reliability: The capacity of the rater or test to reproduce results in the same research setting (Gwet, 2014).

Manual wheelchair: A wheeled mobility device with a seating area which is propelled by hand to help a person who has difficulty walking or moving around (World Health Organization, 2013b).

Peer-mentorship: Peer mentorship can be defined as "building a professional relationship between the mentor and the mentee over time, consisting of nurturing, educative and productive elements" (Aston & Molassiotis, 2003) (page 203).

Wheelchair maintenance: Methods and procedures for keeping a manual wheelchair in a good and appropriate condition (Cicenia, Hoberman, & Sampson, 1956).

Wheelchair mobility: The ability to use a wheelchair independently and perform different activities by participating in the community (Auger et al., 2010).

Acknowledgements

First, I would like to express my appreciation to the participants who made this project possible. I would especially like to extend my thanks to all mentors and mentees, whose knowledge, experience and time was a great asset to this project.

I feel privileged to have been guided by Dr. Bonita Sawatzky and Dr. Ben Mortenson. My achievements would not have been possible without their unconditional support. Being miles away from Vancouver, you two truly supported me and cared about my well-being. You believed in my abilities and guided me through the long process. To Dr. Linda Li, thank you for your guidance and support. Your advice throughout this process helped us to shape a better project.

I would also like to acknowledge Ian Denison for sharing his knowledge and time. We could not complete this project without your help and support.

Dedication

To Mahsa,

I would like to dedicate this thesis to my wife, Mahsa, who has given me so much love and tremendous support. I thank you for believing in me and I feel so fortunate to have you in my life.

Chapter 1: Introduction

1.1 Epidemiology of wheelchair use

Manual wheelchairs are one of the most common assistive devices used by individuals with mobility impairments (World Health Organization, 2008). In 2001, it was estimated that 155,000 community-dwelling Canadians used a manual wheelchair for their mobility (Shields, 2004). In 2012, the number of Canadian manual wheelchair users was estimated at 197,560 (Smith, Giesbrecht, Mortenson, & Miller, 2016). Higher life expectancy (Kontis et al., 2017), and assistive technology improvement (Cook & Polgar, 2014) may support the increase of wheelchair use from 2001 to 2012. In 2010, it was estimated that 3.6 million non-institutionalized individuals over the age of 15 in the United States used a wheelchair (U.S. Census Bureau, 2012). Worldwide, in 2013, the number of wheelchair users exceeded 70 million (World Health Organization, 2013c). The majority of manual wheelchair users are people who are 65 or older (Best, Routhier, & Miller, 2015). As the number of Canadians over the age of 65 doubles over the next 25 years, and as disability rates increase even more dramatically from lifelong diseases such as stroke and diabetes, an exponential increase in the number of manual wheelchair users can be anticipated (Cranswick & Dosman, 2008; Government of Canada, 2010).

Improvement in design and production of bicycles and automobiles (Hadland & Lessing, 2016; Sparke, 2002), are being applied to manual wheelchairs (McLaurin, 1990; PDG Mobility, 2012; Reznik, 2016; Simpson, 2005). Materials such as carbon fiber and aluminum offer manufacturers opportunities to design and produce wheelchairs that are more stable and lighter. Despite these

developments the main components of wheelchairs have generally remained unchanged as illustrated in Figure 1-1 (Model System Knowledge Translation Experts, 2011).

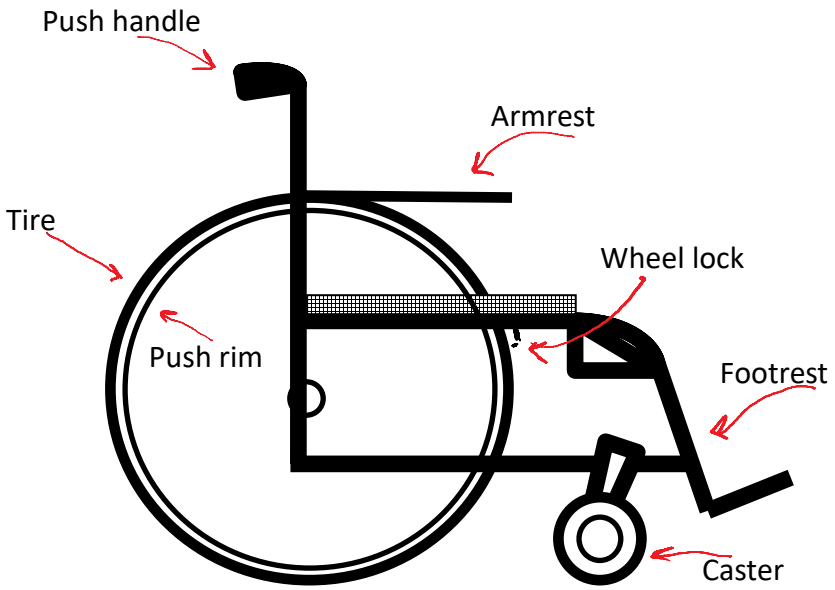

Figure 1-1 Manual wheelchair components

A suitable wheelchair is one that fits the wheelchair user, addresses the wheelchair user's needs, and is not costly to maintain (World Health Organization, 2008). A wheelchair that meets these requirements can improve the level of participation and independence achieved by a wheelchair user (Burkle, 2006; Seelman, 2011). Access to the right wheelchair and wheelchair services is now recognized as a human right for people with disabilities (Burkle, 2006; World Health Organization, 2008).

1.2 Importance of maintenance

Wheelchairs not maintained appropriately can cause accidents and injuries (Kirby & Ackroyd-Stolarz, 1995). To reduce wheelchair-related accidents and improve wheelchair user

participation, the World Health Organization suggested wheelchair maintenance be adopted as a policy to enhance wheelchair safety (World Health Organization, 2008). Fitzgerald et al. found that over a six-month period only 26% of manual wheelchair users performed manual wheelchair maintenance on their manual wheelchairs, 16% performed general maintenance, and 27% repaired a tire. Neither the duration of manual wheelchair use nor the age of the wheelchair user was associated with wheelchair repair or maintenance frequency (Shirley G. Fitzgerald et al., 2018).

The outcomes of wheelchair maintenance have been investigated in only a few studies. A series of studies by Sawatzky et al. which evaluated the effect of tire pressure on rolling resistance (Sawatzky & Denison, 2009) found that the level of pressure in pneumatic tires has an effect on rolling resistance, which also affects energy expenditure (Sawatzky, Miller, & Denison, 2005). In other words, underinflated tires significantly increased energy expenditure. Rolling resistance is a major adverse factor in manual wheelchair propulsion efficiency (de Groot et al., 2007). Sawatzky et al. compared three different tire pressures (100 psi, 75 psi and 50 psi) and discovered there was a significant increase in rolling resistance between 100 psi and 50 psi (Sawatzky, Kim, & Denison, 2004).

In addition to tire pressure, there are several components that have an effect on wheelchair propulsion and rolling resistance, which may indirectly cause wheelchair related injuries. Maintenance and repair of a manual wheelchair are critical activities in improving the efficiency and increasing the safety of manual wheelchairs (Bergen, 1997; Hansen, Tresse, & Gunnarsson, 2004). Front casters have been found to have a significant impact on wheelchair maneuverability

and rolling resistance (Axelson, Chesney, Minkel, & Perr, 2006). Consequently, maintaining the front casters is recommended to facilitate wheelchair maneuverability (Callahan, Nash, & Cowan, 2011; Medola, Elui, Santana, & Fortulan, 2014).

1.3 Potential adverse outcomes of poorly maintained wheelchair (accident and breakdowns)

Wheelchair-related accidents are one of the main safety issues for manual wheelchair users. Wheelchair breakdowns and accidents are common and can result in user injuries (Calder & Kirby, 1990; Edwards & McCluskey, 2010; Kirby & Ackroyd-Stolarz, 1995; Nelson et al., 2010; Ummat & Kirby, 1994; Xiang, Chany, & Smith, 2006). In the United States, the number of individuals treated in emergency rooms as a result of wheelchair-related accidents doubled to 100,000 cases from 1991 to 2003 (Xiang et al., 2006). Poor wheelchair maintenance (Calder & Kirby, 1990) and component failure (Kirby & Ackroyd-Stolarz, 1995; Young, Belfield, Mascie-Taylor, & Mulley, 1985) were reported to be the main factors in wheelchair related accidents.

Maintenance is a serious challenge to community-dwelling manual wheelchair users. Unfortunately, only 20% of wheelchair users worldwide have access to appropriate, well-maintained wheelchairs (World Health Organization, 2008). An American study found among full time wheelchair users, 44.8% needed wheelchair repairs and 8.7% had an adverse consequence (e.g., being stranded, being injured, or missing work) (McClure et al., 2009). A study by Chen et al. found that chances of a wheelchair-related accident were ten times more likely for wheelchair users who indicated that no wheelchair maintenance had been performed in the previous three years than those who did perform maintenance (Chen et al., 2011). The

Wheelchair Service Provision Guide recommends follow-up, maintenance and repair procedures (Arledge et al., 2011). Hansen et al. found that wheelchair users whose wheelchairs had received clinical maintenance had significantly fewer wheelchair-related accidents (Hansen et al., 2004).

Overuse injuries are one of the most common problems experienced by wheelchair users (Cooper, Boninger, Shimada, & Lawrence, 1999; Curtis et al., 1999). A study of 100 manual wheelchair users with paraplegia found they were four times more likely to have rotator cuff tears than age-matched controls (63% compared with 15%) (Akbar et al., 2010). More than two-thirds of all manual wheelchair users will experience upper limb pain or injury because of muscle fatigue or overuse injuries (de Groot et al., 2007). Occurrence of these injuries can reduce participation in activities of daily living (Sawatzky et al., 2005; Silfverskiold & Waters, 1991). Improper wheelchair set-up and maintenance are likely major factors contributing to these injuries.

1.4 Wheelchair maintenance training

Several resources providing information about wheelchair maintenance are available including wheelchair manufacturer users' manuals and maintenance checklists (Cooper, 2013; Lukersmith, Radbron, & Hopman, 2013) and books (Cooper et al., 1999; Cooper, Ohnabe, & Hobson, 2016). In my review of the literature, I searched databases including PubMed, Cochrane, CINAHL and Embase. I used following keywords; manual wheelchair, maintenance, and repair. Two wheelchair maintenance programs were identified. One program is provided by World Health Organization (World Health Organization, 2013c) and the other by Maria Toro from University of Pittsburgh (Toro et al., 2017).

Guidelines on the provision of a manual wheelchair in less resourced settings were released in 2008 (World Health Organization, 2013b). World Health Organization then developed the Wheelchair Service Training Package: Basic Level (World Health Organization, 2013c). The main goal of this program was to develop an individual's skills and knowledge in wheelchair service delivery. The program's target population was wheelchair service providers. The package contains two main sections: 1) Core knowledge covers types of wheelchair users, appropriate wheelchair selection, wheelchair services, parts of the wheelchair, and transferring to/from a wheelchair. 2) Wheelchair service provides information about necessary procedures to use for referrals, appointments, assessments, ordering, user training, maintenance, and repairs. In 2013, World Health Organization released the Wheelchair Service Training Package: Intermediate Level (World Health Organization, 2013b). The target audience of this training package was personnel and volunteers (e.g., occupational therapists, physiotherapists, community health care workers, and community-based rehabilitation workers) who deliver wheelchair service training.

Toro et al. developed a wheelchair maintenance-training program for manual and power wheelchairs for clinicians and technicians (Toro et al., 2017). The training materials, which are not publicly available, included PowerPoint presentations, videos, checklists, reminder cards, and a clinician reference manual. Training was divided into two levels. The first level included six hours of presentations and hands-on practice, and the second level required clinicians to teach wheelchair users both power and manual wheelchair maintenance procedures in a two-hour session. Toro et al. assessed the performance of clinicians and wheelchair users for each specific task with questionnaires ($N_{\text{manual wheelchair user}} = 17$, $N_{\text{power wheelchair user}} = 21$). The questionnaires

measured two factors: capacity “Can you do X maintenance task” and performance: “If you know how to do it, how often do you do it.” Results indicated a significant increase in clinician capacity/performance from 48.8 (IQR=48.4) (pre-training mean) to 100 (IQR=0) (post-training mean), maintenance knowledge (multiple-choice questions) from 56.8 to 84.1, and in manual wheelchair maintenance (open-ended question) from 26.8 to 51.8. However, given the study design, we cannot conclude that clinicians or wheelchair users were able to perform these tasks.

There is no evidence to show the impact of wheelchair maintenance programs on wheelchair users. Existing wheelchair maintenance programs are designed for clinicians, and wheelchair users are not the direct consumers of existing wheelchair maintenance programs. As the scope of rehabilitation expands, there has been a call to include patient/user learning as a means to improve the outcomes of rehabilitation (Fuhrer & Keith, 1998; Mannerkorpi & Gard, 2003; McNevin, Wulf, & Carlson, 2000). World Health Organization’s wheelchair service training package is accessible through WHO website in more than one language, but World Health Organization does not measure or report the effectiveness of their program. In some cases, such as Mario Toro’s wheelchair maintenance training program, the programs are not readily accessible. To-date, there is no manual wheelchair training program developed with a focus on training the wheelchair user and their caregiver.

1.5 Peer mentoring program

A significant amount of manual wheelchair information (i.e., wheeling strategy, skill and wheelchair set-up) has been disseminated over past decades, but most has been directed to clinicians and technicians and not wheelchair users. (Best, Kirby, Smith, & MacLeod, 2005;

Chow & Levy, 2011; Coolen et al., 2004; de Groot et al., 2007; Hurd, Morrow, Kaufman, & An, 2008; Kirby, Swuste, Dupuis, MacLeod, & Monroe, 2002). Literature reported wheelchair training, which performed by clinicians was efficacious, safe and practical (Best et al., 2005). Training, which perform by clinicians, improve the quality of life and increase the community participation of the wheelchair users but access to trained clinicians is one of the most important limitations and challenges (Giesbrecht & Miller, 2017). Clinician based wheelchair maintenance training, which is at its infancy, reported a positive impact on maintenance knowledge (Toro et al., 2017) Although wheelchair maintenance training by clinicians is useful but is limited. Therefore, we decided to design a user centered training for manual wheelchair user and use a peer-mentorship approach to disseminate knowledge about how to properly set up and maintain a manual wheelchair with the objective of making a user's wheelchair easier to propel and safer to use, while also reducing the rate of overuse injuries. Peer-training could be a suitable and feasible model to provide the existing knowledge about wheelchair maintenance to manual wheelchair users.

Peer-training approaches have become a new direction in health care (Best, Miller, Eng, & Routhier, 2016). Peer mentors share similar characteristics and are usually nonprofessional individuals who receive quality training that enables them to provide unique resources to offer their peers (Dennis, 2003; Dorgo, Robinson, & Bader, 2009). Peer mentorship is a reliable method for delivering knowledge and skill to the wheelchair user population (Standal & Jespersen, 2008). With peer-mentorship, the mentor becomes a model for the mentee and can demonstrate the range of skills and techniques that can be mastered by wheelchair users (Standal & Jespersen, 2008). Veith et al. emphasized that peer mentorship improves the quality of the

relationship and its components (credibility, equitability, mutuality, acceptance, normalization) in spinal cord injury populations (Veith, Sherman, Pellino, & Yasui, 2006). In peer mentorship, knowledge and skills are transferred from peer mentors to peer mentees (Eby, 1997). Satisfaction for both mentors and mentees is another positive outcome of peer mentorship relationships (Allen, Poteet, & Burroughs, 1997).

Peer mentorship has been used in health care, especially nursing (Dyer, 2008; May, Day, & Warren, 2006) and also occurs in other disciplines such as management (Eby, 1997) and sports to improve the skills in individuals with disabilities (Standal & Jespersen, 2008). A qualitative study by Standal and Jespersen indicated that peer learning improved a manual wheelchair user's mobility (Standal & Jespersen, 2008). Peers with similar experiences may have a better understanding of each other, and experienced peers (mentors) were perceived as valuable models for the novice participants (Standal & Jespersen, 2008). This model is often used in a school setting. Peer-evaluation is a process through which students and instructors share in the evaluation of students' work (Sivan, 2000).

Given the promising potential of peer mentorship, we developed a peer mentorship program for manual wheelchair skills training. This program involves a workshop and one-on-one peer-sessions. The workshop includes multi-media educational materials that can be used to train both wheelchair users and their caregivers. We trained mentors to deliver wheelchair maintenance knowledge to their peers and caregivers during one-on-one training sessions. It was important to include caregivers in this program, because some wheelchair users could be

physically unable to perform some maintenance tasks but could direct caregivers to perform them.

1.6 Creating learning materials, workshop and evaluation test

Various resources are available for manual wheelchair maintenance. One common source is the wheelchair manufacturer. Manufacturers are required to provide wheelchair maintenance instructions in the wheelchair's user manual (Rehabilitation Engineering and Assertive Technology Society of North America, 2009). Other resources are available, often online, such as maintenance checklists (Cooper, 2013; Government of South Australia, 2017) or professional organizations including the World Health Organization and biomedical and rehabilitation engineering (Cooper, 1998; Cooper, Ohnabe, & Hobson, 2007). Unfortunately, as noted above, most learning material and training is designed for clinicians and service providers, not for wheelchair users. Also, there were no assessment to evaluate the effectiveness of the material and training provided.

Our goal was to develop and implement a manual wheelchair-training program to educate the wheelchair users. To reach this goal, we created open access learning materials that we published on our website (*www.iwheel.ca*). We also developed two tests to assess manual wheelchair maintenance: a test to evaluate a user's knowledge of manual wheelchair maintenance and a test to evaluate manual wheelchair maneuverability.

1.6.1 Developing the wheelchair maintenance training program

The wheelchair maintenance-training program is a peer-training program created specifically for the wheelchair user. Developing this program included delivering the knowledge to mentors by running a full day workshop accompanied with one-on-one peer-sessions (to train the mentees), creating learning materials (documents and videos), creating a website, developing evaluation tests (knowledge test, wheelchair maneuverability test), and creating forms and questionnaires. These components were developed before recruiting participants. The reminder of this chapter outlines how we developed the content for this training program.

1.6.2 Creating wheelchair maintenance knowledge materials

Learning materials were developed based on the evidence in the literature and experience of the wheelchair specialist regarding manual wheelchair maintenance (RESNA, 2009; Sawatzky & Denison, 2009; Sawatzky et al., 2004; Sawatzky et al., 2005). We had the assistance of Mr. Ian Denison, a physiotherapist who is an equipment evaluation specialist at GF-Strong Rehabilitation Centre, Vancouver, Canada. He has over 25 years of experience in teaching wheelchair skills and maintenance to primary therapists. Mr. Ian Denison helped us to develop learning materials (Denison, 2016), run a workshop to train mentors, and develop a manual wheelchair maintenance knowledge test to evaluate mentees. All knowledge materials were finalized and approved by Dr. Bonita Sawatzky and Dr. Ben Mortenson for use in this feasibility study. Based on National Institute of Health recommendation, evidence-based studies are defined as studies with previous research which led to systematic reviews and metanalysis. However, our study is a feasibility study due to limited research on this topic (National Institude of Health, 2018).

1.6.3 **Developing learning material content, video, website and the use of social media**

The wheelchair maintenance learning materials we created include a written manual, as well as videos and photos, all of which are available on the program's website at (*www.iwheel.ca*). We published a 20-page wheelchair maintenance manual with a combination of text and pictures. It is available in both Word and PDF formats at http://www.iwheel.ca/documents/. This manual provides the reader with a list of appropriate tools required for wheelchair maintenance and useful information about wheelchair fasteners such as nuts, bolts, and screws. The manual includes instructions on how to adjust and maintain parts such as bearings, wheel locks, casters and caster stems, as well as tires. In addition, the manual also provides instructions about adjusting for toeing error (when the rear wheels are not parallel to each other), cleaning, and lubricating. We created more than 100 minutes of wheelchair maintenance-learning videos in which Mr. Ian Denison explains and demonstrates the various maintenance activities. These videos are available at http://www.iwheel.ca/iwheel-videos/.

The wheelchair maintenance learning materials are published on a number of social media platforms, including Facebook, Twitter, and YouTube. These platforms were selected to make information accessible to all wheelchair users and more specifically, participants in our research project.

1.6.4 **Creating questionnaire and evaluation forms**

We developed questionnaire and evaluation forms to record information from the feasibility study and to track participants' acquisition of knowledge of wheelchair maintenance activities. A

summary of all forms and questionnaires is available in Table 1-1. A copy of each questionnaire and form is available in the Appendices section of this thesis.

Table 1-1 Form and questionnaires

Name of the form /questionnaire	Purpose of the form	Response option	Completed by	Appendix
Manual wheelchair knowledge test	To measure the knowledge of the mentees about manual wheelchair maintenance	Multiple questions	Mentee	Appendix B
Mentor Workshop Evaluation form	To evaluate the wheelchair maintenance workshop and the facilitator	Dichotomous scale Comparison scale Comment	Mentor	Appendix B
Workshop Facilitator Evaluation Form	To evaluate the workshop and mentor	Dichotomous scale Comparison scale Comment Likert scales	Workshop facilitator	Appendix C
Self-efficacy Questionnaire	To measure the self-efficacy of the mentee before and after wheelchair training program	Agreement scale Comment Likert scales	Mentee	Appendix D
Mentee Knowledge and Maintenance Tracking form	To trace the acquisition of knowledge and maintenance activity of mentee	Dichotomous scale Frequency scale Comment Likert scales	Mentee	Appendix E

Name of the form /questionnaire	**Purpose of the form**	**Response option**	**Completed by**	**Appendix**
Mentor Peer-mentorship Evaluation form	To evaluate the peer-session	Dichotomous scale Comparison scale Comment Likert scales	Mentor	Appendix F
Mentee Peer-mentorship Evaluation form	To evaluate the peer-session	Dichotomous scale Comparison scale Comment Likert scales	Mentee	Appendix G
Peer-mentorship observation form	To record start/end time, number of reviewed topics, problems and comments about the one-on-one peer-session	Frequency scale Comment	Research assistant	Appendix H
Mentee Exit survey	To evaluate the acceptability of the wheelchair maintenance program	Likert scales Comment	Mentee	Appendix I
I-WHEEL checklist	To track the task/data collection required during each visit	Comment	Research assistant	Appendix J

1.6.5 The global research platform

The Global Research Platform is a web-based data collection system provided by the Rick Hansen Institute and is approved by the University of British Columbia Ethics research board (Rick Hansen Institute, 2011). We used this platform to collect results from the demographic forms and the wheelchair maintenance knowledge test. We uploaded the demographic forms and three versions of the wheelchair maintenance knowledge test to the global research platform. Next, we created a unique study identification code for each participant (mentor/mentee), assigned the correct set of forms to each study identification code, and asked the participant to complete the assigned forms/questionnaire at the end of each visit.

1.7 Thesis outline

This thesis consists of five chapters. Following the introductory chapter, Chapters 2 and 3 describe the reliability results for the 3-cone test and manual wheelchair maintenance knowledge test respectively. Chapter 4 explains the peer-mentorship feasibility study including plans, recruitment, data collection, and data analysis. Chapter 5 outlines the study's discussion and conclusions and details the findings, as well as the significance of the research, limitations, and future research directions

1.7.1 Chapter 2: Test-retest intra-rater reliability of the 3-cone test

Maintaining and adjusting front casters is an important topic in our wheelchair maintenance manual. In Chapter 2 of this thesis, the method we developed to measure the effect of front caster maintenance is explained. We modified the indoor circuit test (which was part of Queensland Evaluation of Wheelchair Skill test) (Gollan, Harvey, Simmons, Adams, & McPhail, 2015) to

focus on front caster performance and wheelchair maneuverability. The focus of this maneuverability test is on the front caster performance. Cleaner front casters will wheel and move smoother, which resulted in making clearing front casters as one of the topics in the wheelchair maintenance education program. We then evaluated the reliability and of this test before using it in our feasibility study. We performed a test-retest reliability test for the 3-cone test using able-bodied and wheelchair user participants.

1.7.2 Chapter 3: Test-retest intra-rater reliability of the wheelchair maintenance knowledge test

In this chapter we explained the three-step process to develop the wheelchair maintenance knowledge test. Then, we evaluated the internal consistency and test-retest reliability of the test. Able-bodied and wheelchair users were recruited to participate in a test-retest reliability evaluation of the manual wheelchair maintenance knowledge test. A copy of the wheelchair maintenance knowledge test is available in Appendix A.

1.7.3 Chapter 4: Can manual wheelchair maintenance program improve wheelchair efficiency and knowledge about wheelchair maintenance, a peer-led feasibility study using a pre-post comparative design

In this chapter, we evaluated the five feasibility outcomes of the manual wheelchair maintenance training program. The key outcomes were recruitment capability and data collection procedure. We also evaluated the acceptability, resources and participant responses.

1.7.4 **Chapter 5: Discussion and future direction**

This chapter summarizes the main findings of the three previous chapters and briefly explains how these findings can be used in the future to develop a randomized control trial. We found out that manual wheelchair maintenance training is feasible. However, scheduling is one of the challenges to develop the program.

Chapter 2: Test-retest, inter-rater reliability of the 3-cone test

Summary

Aim: The aim of this study was to assess the test-retest intra-rater reliability and validity of the 3-cone test, which is a new measure that we designed to evaluate wheelchair user's maneuverability using their manual wheelchairs. **Design:** This study employed a test-retest design. Each participant completed the three 3-cone test trials approximately two weeks apart. **Setting:** Testing took place at an interdisciplinary research center focused on spinal cord injury. **Participants:** A convenience sample of five people with spinal cord injury (n=5, 23%) and seventeen able-bodied individuals (n=17, 77%) participated in this study. **Method:** Each participant completed three 3-cone test trials. These trials were scheduled on two non-consecutive days within a two-week period. To complete the trial, participants were supplied with a seat height adjustable manual wheelchair. Intra-class correlation coefficients were used to measure the reliability of the 3-cone test and a 2-way ANOVA was used to compare the wheelchair users (experienced users) and able-bodied users (novice users). **Results:** The average time (in seconds) of the 3-cone test completion for wheelchair users was 18.16 at baseline and 17.99 at retest. For able-bodied individuals, the result was 23.89 at baseline and 22.23 at retest. These results indicated that experienced wheelchair users performed better. The intra-class correlation coefficients for wheelchair users and able-bodied participants were 0.978 and 0.881 respectively. The 2-way ANOVA (test between subjects) showed a statistical difference between wheelchair user and able-bodied population. **Conclusions:** The 3-cone test achieved a high reliability score for both experienced and novice populations.

2.1 **Introduction**

Approximately 3.8 million (13.7%) Canadian (Government of Canada, 2013) and 50 million (15.1%) American adults have a physical disability (National Institute of Health, 2012; National Institute of Health Statistics, 2015). Mobility issues are the third leading cause of disability (Government of Canada, 2013). Assistive technology is commonly used to address mobility challenges (Bateni & Maki, 2005; Manton, 1989). For example, about 1% of the population with a mobility disability use a manual wheelchair as their means of getting around (World Health Organization, 2008). Purchase cost and maintenance costs of mobility devices have been identified as two primary reasons as to why more than 300,000 Canadians do not have appropriate (well maintained) mobility devices (Government of Canada, 2009).

To participate in daily activities, wheelchair mobility is critical. Wheelchair mobility is an important factor in wheelchair users' daily activities and ability to participate (van der Woude, de Groot, & Janssen, 2006). Characteristics of the user (e.g., skill), the wheelchair (e.g., rolling resistance and maneuverability), and the environment affect wheelchair mobility. A manual wheelchair's front casters have a major influence on wheelchair maneuverability due to their ability to rotate and swivel in different directions (Axelson et al., 2006). Size (e.g., 4", 5", and 6") and weight distributions of front casters have a major impact on rolling resistance for both indoor and outdoor surfaces (Chan, Eshraghi, Alhazmi, & Sawatzky, 2017; Zepeda, Chan, & Sawatzky, 2016).

To quantify wheelchair mobility, a variety of measures have been developed. In the laboratory, drag force (Groot et al., 2005) and turning resistance (Frank & Abel, 1989) tests can measure the

rolling resistance and maneuverability of a manual wheelchair independent of the user. In both tests, wheelchair users sit passively on a manual wheelchair. This eliminates the confounding effect of wheelchair skills on these outcomes. However, neither the wheelchair treadmill nor the turning resistance apparatus are commonly available to clinicians. Several clinical measures assess propulsion ability/function of wheelchair user. The 6-minute push test was developed to assess the wheeling fitness (Callahan et al., 2011; Cowan, Callahan, & Nash, 2012) and the Wheelchair Skill Test measures the user's ability to perform discrete skills (e.g., turn while moving, roll forward, turn 180° in place and manoeuvre sideways) (Kirby, Smith, & Parker, 2016).

Front caster wheels are an important element of a manual wheelchair's configuration and have a strong impact on manual wheelchair maneuverability (Medola et al., 2014). Axelson et al. reported that front casters have a great influence on the wheelchair maneuverability on non-linear propulsion (Axelson et al., 2006). Wheel, bearings, caster axle and fork stem bearing are the main part of the manual wheelchair front casters. Front casters are easily become damaged because they hit street curbs, walls or door frames. They also absorb dirt very fast due to their contact to different types of indoor and outdoor flooring. Maintaining and cleaning the front casters would improve the performance of the front caster thus wheelchair can maneuver better.

Most maneuverability tests evaluate the linear propulsion of the wheelchair user (Callahan et al., 2011). However, the *Slalom test* is performed on a curved shaped line. The *Slalom test* is a reliable test in the rehabilitation and research setting, but this test measures the total performance

of the individual with spinal cord injury on a manual wheelchair and does not evaluate the front caster specifically (Gagnon, 2011). We modified the *Slalom test* and developed the 3-cone test so that maneuverability of a manual wheelchair could be quickly assessed with materials that are available in a clinical environment. To examine the measurement properties of this new measure we assessed its reliability, the minimal detectable change (i.e., level of agreement, intra-class correlation coefficients, standard error of measurement and minimal detectable change) and extreme group validity.

2.2 Hypotheses

We had two main hypotheses:

1). We hypothesized that the reliability of the ICC would be more then 0.80

2) We hypothesized that experienced wheelchair users would take less time to complete the 3-cone test than novice users.

2.3 Methods

The study used a test-retest design in which data was collected on two non-consecutive days within a two-week period. This study received ethical approval from the local university ethics review board (Certificate #: H15-00046). Guidelines for reporting reliability and agreement studies were used to report these findings (Kottner et al., 2011).

2.3.1 Participants and recruitment

Wheelchair users and able-bodied subjects were recruited from a spinal cord injury research center. In the ideal world we want to compare experience wheelchair user with a novice

wheelchair user. Novice wheelchair users consists of individuals with recent injury or individuals with no experience in using manual wheelchairs. Due to limited access to recently injured population, we recruited able-bodied population as a replacement for novice wheelchair users. Individuals were selected if they were 19 years of age or older, able to provide their own consent, could use a manual wheelchair without pain, and could independently transfer themselves. Participants were excluded if they could not communicate in English or could not independently propel a manual wheelchair for 30 meters. For participants with spinal cord injury, we excluded those who had their injury within the previous 6 months. Participants were recruited using posters displayed at the research center and an advertisement posted on the research center's website.

2.3.2 **The 3-cone test**

As illustrated in Figure 2-1 the 3-cone test consisted of three cones positioned in a straight line, one meter apart. Each cone was placed at the center of a 50cm radius marked circle. The starting point (*point A*) is set 10 meters from the first cone. Participants began at start line and wheeled around the cones in a figure-8 type pattern. After the third cone, participants wheeled to the finish line by going around the cones in the opposite direction. Time (sec) between start and finish lines was recorded for each trial.

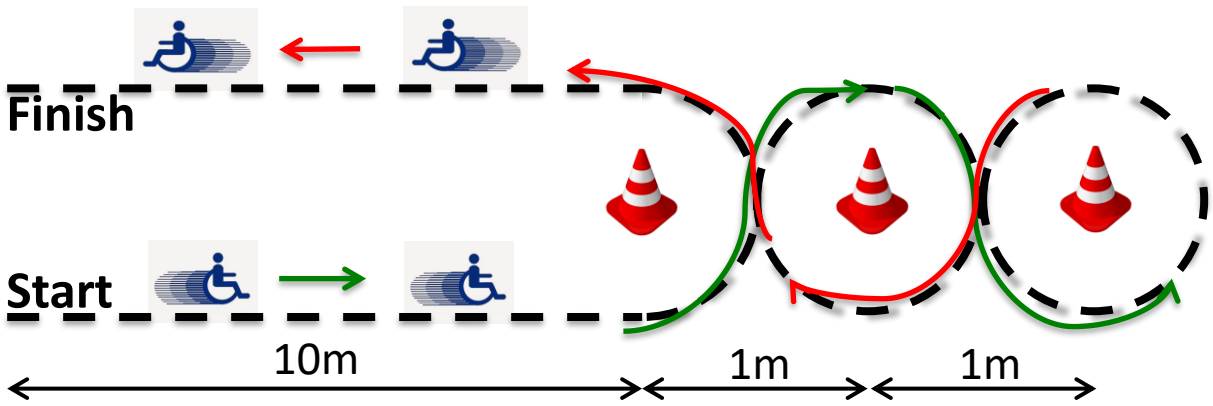

Figure 2-1 The 3-cone test

2.3.3 Data collection and procedure

Participants came to the test center two times on two non-consecutive days within two weeks to perform the 3-cone test. The height of the wheelchair was adjusted so that participants had adequate contact with the wheelchair rims. The elbow angle was measured with a goniometer while participant grasped the top of the rim to ensure there was an elbow angle between 90 and 120 degrees (Medola et al., 2014). Participants practiced using the manual wheelchair before the initial trial to ensure that they were familiar with the elevation chair. All trials for this study were performed using the same ultralight Elevation wheelchair™ (PDG Mobility, 2012) with 4-inch casters. The rear tires were inflated to 120psi (85% of the maximum pressure) at the beginning of each session (Sawatzky & Denison, 2009; Sawatzky et al., 2004).

Each participant completed three 3-cone test trials approximately two weeks apart. Participants were requested to abstain from moderate to hard physical activity on test days. They were given the opportunity to take a break between trials to reduce fatigue effects. The first two trials of each session were considered as training trials and only data from the last (third) trial were used

for analysis. For the second session, the wheelchair height was adjusted to reproduce the same, previously recorded, elbow angle.

2.3.4 **Statistical analysis**

To describe the sample, we calculated the mean difference as well as the standard deviation for the third trial of the baseline and second sessions for each group. The level of significance was set at $p<0.05$. We used Mahalanobis distance to check the data for any outliers. We made Bland-Altman plots to determine if there were any systematic differences between the third trial and mean differences at each time point. Regression analysis was used to identify any linear trend or existing of proportional bias.

To evaluate the reliability of the 3-cone test, we calculated a two-way mixed intra-class correlation for each group (able-bodied and wheelchair user) separately as well as for all participants together. To evaluate the reliability of the 3-cone test, we calculated the standard error of measurement. We also reported a statistical estimate of the smallest amount change that was detectable (minimal detectable change) for each group. To determine the difference between experienced and novice users, we performed a two-way ANOVA. SPSS version 23 was used for all analyses (IBM Analytics, 2016).

2.4 **Results**

Twenty-two participants were recruited to participate in the study. Demographic information about participants is provided in Table 2-1. As noted in the table, experienced wheelchair users were older than novice users and were predominantly male, while able-bodied participants had a

relatively equal division between men and women. One participant could not attend the second session due to a wrist injury that was unrelated to the study.

Table 2-1 Demographic table

Parameter	**Mean ± SD / N (Count)**	
	Wheelchair users	***Able-bodied***
	5 (23%)	17 (77%)
Age (Y)	45 ± 8.25	28.06 ± 9.34
Sex		
Male	4 (80%)	9 (52%)
Height (cm)	179 ± 9.57	174 ± 10.00
Weight (kg)	80.31 ± 13.26	72.25 ± 13.17
Education		
High school	0 (0%)	1 (6%)
College diploma	2 (40%)	2 (12%)
University degree	0 (0%)	11 (65%)
Graduate studies	3 (60%)	2 (12%)
Post graduate	0 (0%)	1 (6%)
Diagnosis of wheelchair users		
Complete spinal cord injury	3 (60%)	
Incomplete spinal cord injury	2 (40%)	
Hours of wheelchair use per day	11 ± 5	
Diagnosis Level		
T4	1 (20%)	
T5	2 (40%)	
T6	1 (20%)	
T12 / L1	1 (20%)	
Length of diagnosis (Y)	20 ± 15	

Bland and Altman plot describes the agreement between tests and re-test measurements (Bland & Altman, 2007). The graph displays a scatter diagram of the differences plotted against the average of the test and re-test. A visual demonstration of this plot showed heteroscedasticity for the test-retest result from the 3-cone test. This result confirmed by linear regression analysis (p= 0.352). The mean difference is 1.37 and the upper and lower limits of agreements are 7.64

and -4.91 respectively. The Mahalanobis distance indicated the existence of one outlier (distance: 20.58, *p*=.00003) in the data set and the outlier was removed for subsequent analysis. 0gure 2-2 shows the normal distribution of data above and below the mean difference line.

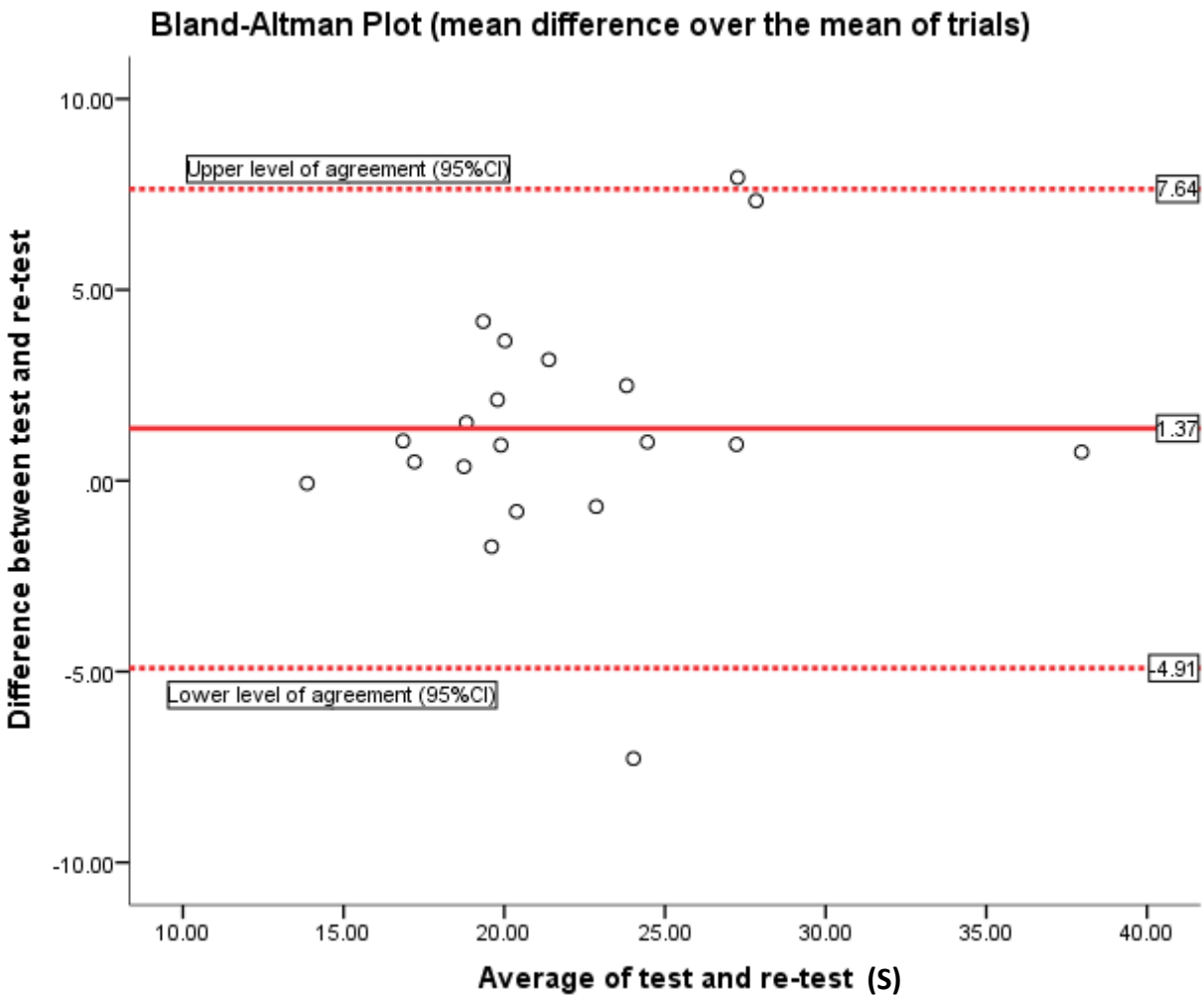

Figure 2-2 Bland-Altman Plot for all participants (without outlier). Dashed lines indicate the limits of agreement. Solid line: mean difference. Circles: test-retest results

The test-retest reliability analysis was conducted for both wheelchair user and able-bodied groups and the combined sample. The 3-cone test trials were performed approximately two

weeks apart (*M*= 15.7d, SD=5.25). Table 2-2 summarizes the results for intra-class correlational coefficients, standard error of measurement, and minimal detectable change.

Table 2-2 Mean (seconds), SDs, SEM and ICCs for 3-Cone test at Baseline and Retest (16 days after)

Group	**Baseline**	**Retest**	**ICC**	**ICC (95% CI)**	
				Lower bond	**Upper bond**
Wheelchair users	18.16 ± 3.60 SEM=1.80 $MDC_{95\%}$=5.08	17.99 ± 3.95 SEM=1.98 $MDC_{95\%}$=5.59	.991	.857	.999
Able-bodied	23.89 ± 5.68 SEM=1.42 $MDC_{95\%}$=4.01	22.23 ± 5.24 SEM=1.30 $MDC_{95\%}$=3.67	.881	.668	.959
Combined	22.75 ± 5.75 SEM=1.29 $MDC_{95\%}$=3.64	21.38 ± 5.20 SEM=1.16 $MDC_{95\%}$=3.27	.907	.765	.963

Note: Values are mean±SD or otherwise indicated.
Abbreviation: ICC, Intra-class correlation coefficients; CI, confidence interval; SEM, Standard Error of Measurement; MDC, Minimum Detectable Change.

We performed a two-way ANOVA to see if there was statistically significant difference between the experienced and able-bodied group during the test and re-test. Results from the 2-way ANOVA showed that there was no interaction effect between participant groups (able-bodied or wheelchair user, F=.133, p= .718) and there was no main effect for time (F= .133, p=.718). However, there was a main effect for group (able-bodied, wheelchair users) (F= 5.829, p=0.21).

2.5 Discussion

This is a first study to evaluate the reliability and validity of a novel 3-cone test focused on wheelchair users' maneuverability. The intra-class correlational coefficients results showed there was partial support for the first hypothesis. For the experienced user group, the lower bound of the inter-class correlations coefficient was >.8. The Intra-class correlation coefficients value ≥.80

indicates that the reliability of the 3-cone test is considered to be good/excellent and appropriate for use in clinical care or research among experienced users (Koo & Li, 2016; Portney, 2009). . However, the lower bond of the 95% confidence interval for able-bodied participants was less than 0.8. The small sample size might have contributed to the wide 95% confidence interval for the intra-class correlation coefficients. In future studies, individual comparison and interpretation of the findings should be performed with more caution in this population.

This measure demonstrates low standard error. Low standard error of measurement and minimum detectable change can increase precision of results and reduce the sample size of research studies (Frost, Reeve, Liepa, Stauffer, & Hays, 2007). Standard error of measurement and minimum detectable change values found in our study indicated a low variability of results, which was a similar trend to that shown in the "*Slalom test*", which was done by Gagnon et al. (Gagnon, 2011). However, direct comparison of standard error of measurement and minimum detectable change of our study and the "*Slalom test*" is not appropriate due to different sample types and different confidence interval levels (i.e., Gagnon reported %90). Reported confidence interval of our study indicates a high degree of precision (Boswell-Ruys, Harvey, Delbaere, & Lord, 2010) and the 3-cone test can be used to assess the true change over time for both experienced and novice wheelchair users (Fitzpatrick, Davey, Buxton, & Jones, 1998; Hopkins, 2000).

We found mixed support for our second hypothesis that "experienced wheelchair users would complete the 3-cone test faster than novice able-bodied users". The significant ANOVA test results suggests that the 3-cone test distinguishes between experienced and novice wheelchair

user. However, the difference between the lower bound of the confidence interval of the able-bodied group and the upper bound of the confidence interval for the experienced group did not exceed the minimal detectable difference. Hence, the observed difference between groups might be attributed to measurement error and should be interpreted with caution.

The 3-cone test focuses on an individual's ability to maneuver the wheelchair and study showed able-bodied and wheelchair user experienced similar challenges to perform wheelchair skills, there is a question of how these results can transfer from able-bodied to novice wheelchair users (Kirby et al., 2005). Different aspects of manual wheelchair maintenance, especially the front casters, influence maneuverability. The 3-cone test has a potential to be part of manual wheelchair maintenance programs to evaluate the wheelchair maneuverability after performing the maintenance.

The study had two main limitations. First, we used the convenience sampling method for recruitment which limits generalizability and replicability of the findings. A larger sample size with equal distribution of novice and experienced wheelchair users would increase generalizability and replicability of the findings. Second, we used the same sized, height adjustable wheelchair for all participants, so the wheelchair was not individually fitted to the width or weight of participants.

2.6 **Conclusions**

This two-week test-retest study was undertaken to evaluate the reliability of the 3-cone test among wheelchair user and able-bodied populations. The 3-cone test has excellent test-retest

reliability. Overall, the results of the 3-cone test appear to be useful in the clinical setting, but further study is needed to explore how this test can be used in research and clinic.

Chapter 3: Test-retest, intra-rater test of the manual wheelchair knowledge test

Summary

Aim: To examine the intra rater reliability and absolute reliability of a novel test that was developed to evaluate users' knowledge about manual wheelchairs and their maintenance. **Design:** In this psychometric study, each participant completed the wheelchair maintenance knowledge test two times within a two-week period. **Setting:** An interdisciplinary research center focused on spinal cord injury. **Participants:** A convenience sample of individuals with spinal cord injury (N=11, 38%) and able-bodied individuals (N=18, 62%). **Method:** A total of 29 experienced wheelchair users and able-bodied participants contributed to this study. Each participant completed the wheelchair maintenance knowledge test two times within a two-week period. We calculated a Cronbach's alpha to report the internal consistency of the knowledge test items. An intra-class correlation coefficient was used to examine the level of agreement between the test and re-test. Absolute reliability indices (Messick, 1995), including the standard error of measurement and the minimal detectable change, were used to define to what extent the knowledge test varies on test-retest. We performed an independent samples t-test to compare the wheelchair user and able-bodied population. **Results:** Cronbach's alpha supported the internal consistency of the test. Intra-class correlation coefficients for the wheelchair maintenance knowledge test revealed excellent reliability for experienced wheelchair users (ICC= 0.885), as well as novice wheelchair users (able-bodied population, ICC= 0.950). The standard error of mean and minimum detectable change for experienced wheelchair users and novice wheelchair users was 1.65, 4.57; 1.26, 3.49 respectively. The results from independent t-test showed the

significant difference ($p \leq .05$) between wheelchair users and able-bodied individuals.

Conclusions: The test appears to be highly reliable and distinguishes wheelchair users from non-wheelchair users. Future research needs to establish its responsiveness to intervention.

3.1 Introduction

A wheelchair is one of the most common means of mobility among individuals with spinal cord injury. In 2013, the World Health Organization reported that 70 million people worldwide required a wheelchair (World Health Organization, 2013c). There are different types of manual wheelchairs, and depending on their lifestyle, each wheelchair user propels their wheelchair differently. Nevertheless, a well-maintained manual wheelchair will decrease the chances of manual wheelchair accidents; however, a Statistics Canada report indicated that more than 300,000 Canadians do not have a well maintained wheelchair (Government of Canada, 2009).

Wheelchair maintenance has been suggested as a strategy to improve wheelchair safety and performance (Arledge et al., 2011). Retrospective study by Barnard et al. showed the number of wheelchair related accidents increased during 1991 to 2008 (Barnard, Nelson, Xiang, & McKenzie, 2010). The need for wheelchair maintenance will increase as the number of wheelchairs and wheelchair users increase (World Health Organization, 2008). However, regular maintenance is relatively uncommon and only 26% of required wheelchair maintenance was performed in the previous six months (S. G. Fitzgerald et al., 2005). A randomized control study has found that wheelchair maintenance is associated with a reduction in wheelchair related accidents (Chen et al., 2011; Hansen et al., 2004) and improves the safety of wheelchair users (Hansen et al., 2004). Upper limb injuries are another potential source of poorly maintained manual wheelchairs (Mâsse, Lamontagne, & O'Riain, 1992). Chen et al. reported that wheelchair-use behavior is one of the main factors in wheelchair related accidents and that a wheelchair maintenance-training program may decrease the chance of wheelchair related accidents (Chen et al., 2011). A wheelchair maintenance program may help a wheelchair user

understand their manual wheelchair better. World Health Organization developed a basic level wheelchair maintenance package (World Health Organization, 2013c), but its focus was on instructing clinicians, and did not offer any tools to measure the knowledge of wheelchair users or clinicians. In fact, currently there is no tool available to measure and evaluate wheelchair users' knowledge about manual wheelchairs and their maintenance.

The manual wheelchair maintenance test was developed in preparation for an intervention study in the area of manual wheelchair maintenance training. The purpose of this study was to investigate the relative and absolute reliability of manual wheelchair maintenance using a knowledge test for experienced and novice wheelchair users. In particular, we reported the intra-item correlation, intra-rater correlation coefficient, standard error of measurements, and minimum detectible change and finally explored the validity of test by comparing the results from both experienced and novice wheelchair users' groups.

3.2 Objectives

This study had three objectives 1) To determine the internal consistency and inter-item correlation of the wheelchair maintenance knowledge test, 2) To report the relative and absolute reliability of the wheelchair maintenance knowledge test, and 3) To investigate the validity of the wheelchair maintenance knowledge test by comparing the experience and novice users.

3.3 Hypotheses

We had two main hypotheses:

1) The wheelchair maintenance knowledge test would have an intra-class correlation coefficient of more than 0.80.
2) Manual wheelchair users have more knowledge about the manual wheelchair maintenance than able-bodied users.

3.4 Methods

3.4.1 Participants and recruitment

A sample of experienced, community dwelling, active manual wheelchair users (n=11, 38%) and novice able-bodied (n=18, 63%) were recruited. To be included in the study participants needed to be aged ≥19 years and able to read and understand English. They were also expected to be able to use a computer or tablet to answer the questions. Each participant completed the two Wheelchair Maintenance Knowledge Tests two weeks apart. We recruited participants from rehabilitation research facilities via posters and newsletter advertisements. The study received ethical approval from our university's ethical review board (Certificate #: H15-00046), and all participants provided written consent.

3.4.2 The wheelchair maintenance knowledge test

The Wheelchair Maintenance Knowledge Test has 35 multiple choice questions. Questions were developed by the authors of the study, with input from equipment specialist, Ian Denison. After finalizing the questions in terms of content and wording, the questions were categorized by difficulty (i.e., easy, medium and hard). Next, all 35 questions were sorted from easy to hard. The last version of questions used in this study was combination of 9 easy, 9 medium and 17 hard questions.

Data collection and procedure

Participants completed the wheelchair maintenance knowledge test on two days within a two-week period. The order of the questions changed for the day two (re-test). There was only one correct answer for each question. Participants received one point for each correct answer (min=0; max=35). Participants completed the test online using the Global Research Platform (Rick Hansen Institute, 2011).

3.5 Statistical analysis

For the first objective (i.e., to determine the consistency and inter-item correlation of the wheelchair maintenance knowledge test), we used Cronbach's alpha to estimate internal consistency associated with scores derived from questions. For the second objective (i.e., To report the relative and absolute reliability of the wheelchair maintenance knowledge test) we conducted an inter-item correlation to check the correlation between easy, medium, and hard questions. Relative reliability was assessed through the calculation of intra-class correlation coefficients of the wheelchair maintenance knowledge test; with Intra-class Correlation Coefficients values greater than or equal to 0.8 considered good agreement (Richman, Makrides, & Prince, 1980). Standard error of measurement and minimal detectable change were calculated to evaluate the absolute reliability of the wheelchair maintenance knowledge tests. Bland-Altman analysis was used to determine agreement between test and re-test measurements (Bland & Altman, 2007). For the third objective (i.e., to investigate the validity of the wheelchair maintenance knowledge test by comparing the experienced and novice users), we performed a 2-

way ANOVA to statistically compare experienced and novice wheelchair users at two assessment time points.

3.6 Result

Twenty-nine participants were recruited to participate in the study, ranging in ages from 19 to 51 years. Table 3-1 shows the details of the participants. The total mean age of the participants was 35.79 ± 14.83 years, of whom 58.6% were male and 40% used a manual wheelchair.

Table 3-1 Demographic table

Parameter	**Mean ± SD / N (%)**	
	Experienced Wheelchair users 11 (38%)	***Able-bodied Novice users*** 18 (62%)
Age (Y)	46.33 ± 15.04	28.22 ± 9.08
Sex		
Male	8 (47%)	9 (53%)
Height (cm)	174.60 ± 11.91	174.5 ± 9.84
Weight (kg)	87.23 ± 34.44	71.79 ± 12.92
Education		
High school	2 (16.6%)	1 (5.58%)
College diploma	3 (36 %)	2 (11.8%)
University degree	1 (8.3%)	11 (64.7%)
Graduate studies	4 (33.3%)	3 (17.6%)
Post graduate	2 (16.6%)	1 (5.58%)
Wheelchair Experience		
No experience	0 (0.0%)	8 (47.1%)
1 to 24 hours	0 (0.0%)	4 (23.5%)
1 to 30 days	0 (0.0%)	6 (35.2%)
1 to 12 months	1 (8.3%)	0 (0.0%)
More than a year	11 (91.7%)	0 (0.0%)
Diagnosis of wheelchair users		
Complete spinal cord injury	4 (33.3%)	
Incomplete spinal cord injury	7 (58.3%)	
Spina bifida	1 (8.3%)	

3.6.1 **Internal consistency**

Results from the Cronbach's alpha (Lance, Butts, & Michels, 2006) test showed that 93% of items have internal consistent reliable variance, and the “item total statistics” were between .92 and .93 (Cronbach's Alpha >0.9) if non-relevant questions (i.e., “Item Deleted”) were removed from questionnaire.

3.6.2 **Reliability**

The test-retest reliability analysis was conducted for both wheelchair user and able-bodied groups. Experienced wheelchair users had a better score on both assessment days compared to the novice wheelchair users. However, the test-retest reliability results yielded higher Intra-class correlation coefficients for novice wheelchair users. Results from the inter-item correlation showed that there was a high correlation between easy, medium, and hard questions. The highest correlation was between easy and medium questions, and the lowest correlation was between easy and hard questions.

The test-retest reliability analysis was conducted for both wheelchair user and novice able-bodied groups and the combined sample. The 3-cone test trials were performed approximately two weeks apart. Table 3-2 summarizes the results for intra-class correlational coefficients, standard error of measurement, and minimal detectable change.

Table 3-2 Means, SDs and ICCs for 3-Cone test at Baseline and Retest (2 weeks after)

				ICC (95% CI)	
	Baseline	**Retest**	**ICC**	**Lower bond**	**Upper bond**
Experienced Wheelchair users (n=11)	17.09 ± 5.94 SEM=1.79 MDC=4.96	18.82 ± 5.47 SEM=1.65 MDC=4.57	.885	.574	.969
Novice wheelchair users (n=18)	5.55 ± 4.80 SEM=1.13 MDC=3.13	6.11 ± 5.37 SEM=1.26 MDC=3.49	.950	.866	.981
Combined	9.93 ± 7.69 SEM=1.43 MDC=3.96	10.93 ± 8.22 SEM=1.53 MDC=4.24	.967	.929	.984

Note: Values are mean±SD or otherwise indicated.
Abbreviation: ICC, Intraclass correlation coefficients (average); CI, confidence interval.

The Bland-Altman plots were created for the scores at the test and re-test for all the participants (Figure 3-1).

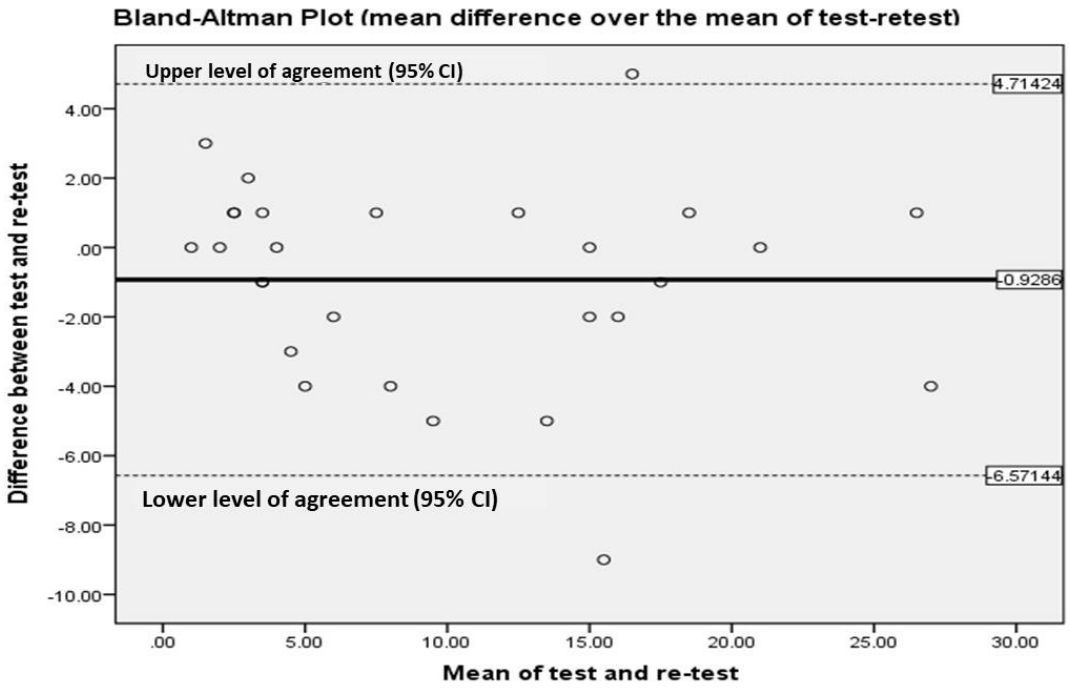

Figure 3-1 Bland-Altman plots for the manual wheelchair maintenance knowledge test between test and re-test. The solid line represents the mean of difference in score, while the dotted lines represent the limits of agreement within a 95% CI

3.6.3 Group comparison

Results from two-way ANOVA showed there was no main effect for time (F= .434, p= .513) and no interaction effect between experienced and novice wheelchair users (F= .164, p= .687). However, there was a main effect for group (wheelchair user, novice able-bodied) (F=42.542, p<0.001).

Table 3-3 Wheelchair maintenance knowledge test group comparison

		MEAN ± (SD)
Wheelchair user	Test	15.636 ± 1.789
	Re-test	17.364 ± 1.789
Novice able-bodied	Test	5.706 ± 1.439
	Re-test	6.118 ± 1.439

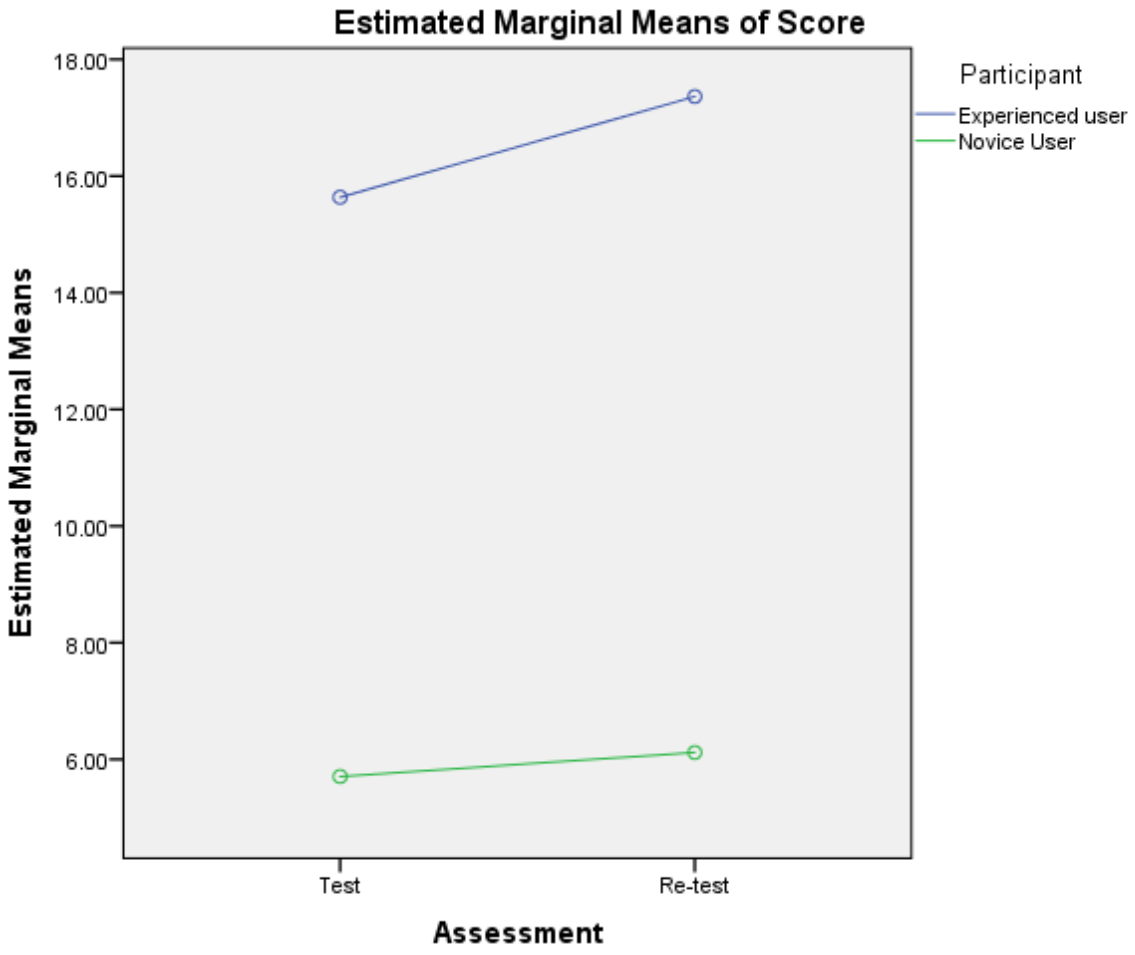

Figure 3-2 2-way ANOVA profile plot of the manual wheelchair maintenance knowledge test results between test and re-test for experienced and novice wheelchair users.

3.7 Discussion

The manual wheelchair maintenance knowledge test is the first tool designed to be freely available specifically to assess the knowledge of wheelchair maintenance, but it is not to be shared. In this study we recruited experienced wheelchair users and novice able-bodied individuals. In the ideal world, the goal is to get new wheelchair users (i.e., without experience) instead of using novice able-bodied individuals. However, due to the challenges of recruiting sufficient wheelchair users, we decided to recruit novice able-bodied individuals. A study by Kirby et al., showed wheelchair users and able-bodied users share same difficulties during wheelchair skill tasks (Kirby et al., 2005). We hoped that novice able-bodied participants could serve as proxies for new wheelchair users, but we recognize these populations differ in many ways. We have organized the discussion based on the study objectives.

3.7.1 Internal consistency

Internal consistency of the questions in the manual wheelchair maintenance knowledge test was excellent (≥ 0.92) and more than recommended scale for the Cronbach's alpha (Cortina, 1993; Lance et al., 2006). Item total statistics results supported the high correlation between questions and indicated that there was no need to remove any questions from the wheelchair maintenance knowledge test. The correlations and reliability between easy, medium, and hard questions supported our prediction about the balance of questions (hardness) and the way the questions were sorted.

3.7.2 **Test-retest reliability**

Our study found mixed support regarding the test-retest reliability. The intra-class correlation coefficient values for the able bodied group and combined sample were well above the acceptable value ≥.90, indicating the wheelchair maintenance knowledge test may be used for individual comparison (Aaronson et al., 2002; Boswell-Ruys et al., 2010; Hafner, Morgan, Askew, & Salem, 2016). However, the lower bond of the 95% confidence interval for experienced wheelchair user was less than 0.8. The small sample size might have contributed to the wide 95% confidence interval for the intra-class correlation coefficients. Experienced wheelchair users may also have been motivated to look for answers to questions they felt uncertain about after the first administration. These results indicated that the wheelchair maintenance knowledge test is a reliable test for use in research and clinical environments among novice able bodied users (Koo & Li, 2016; Portney, 2009).

To identify the lower threshold of changes in the wheelchair maintenance knowledge test that can be measured, we evaluated the standard error of measurement and minimum detectable change. Low standard error of measurement and minimum detectable change in our study indicated a low variability of outcome for the wheelchair maintenance test. Values from this study can be use as cutoff values in future studies.

3.7.3 **Group comparison**

Our finding supports second hypothesis defined as manual wheelchair users have more knowledge about the manual wheelchair maintenance than able-bodied users. Although, novice able-bodied users had higher level of education (i.e., higher college degree in the novice

wheelchair group) but the experienced wheelchair users scored higher in the manual wheelchair maintenance knowledge test. Results from the ANOVA test found that the difference between experienced wheelchair users and the novice able-bodied subjects was significant. Furthermore, our results showed the difference between the lower bound of the confidence interval of the able-bodied group and the upper bound of the confidence interval for the experienced group did exceeded the minimal detectable difference. These results confirmed that the observed difference between groups would likely occur due to the difference between groups. The wheelchair maintenance knowledge test can be used as a tool to differentiate the experienced and novice wheelchair user.

3.8 Conclusions

In summary, the results of this study indicate that the manual wheelchair maintenance knowledge test has high interclass correlations scores, however there are wider confidence intervals among experienced wheelchair users. The test is also able to distinguish between experienced and novice manual wheelchair users. Additional research would be beneficial to improve reliability among experienced wheelchair users.

3.9 Future direction

The manual wheelchair maintenance knowledge test was developed as part of wheelchair maintenance program training. The goal was to use this test to evaluate the knowledge of the participant before and after the training program. With the results from this test, we have a better understanding about the knowledge of wheelchair users. It would be beneficial to see if there is any correlation between knowledge about manual wheelchair maintenance and performing

wheelchair maintenance. Performing a factor analysis could help the researcher and clinicians to understand and investigate the variable (Lawley & Maxwell, 1962). However, a minimum sample size of 100 needed to perform the factor analysis. Item response theory could also be applied to larger samples (Boone, 2016).

3.10 Study limitation

This study had three limitations: First, the sample size. We used convenience-sampling model and were able to recruit 28 participants to complete this study. The results of the study may not be generalizable due to convenience sampling. Second, knowledge about the manual wheelchair maintenance was unknown and there were no other wheelchair maintenance knowledge tests to compare our results. Third, time between test and re-test performed in this study was two-weeks and participants might have recalled their responses to the questions. Additionally, Marx et al. suggested that reliability of the questionnaire for the test-retest is uninfluenced at approximately two-weeks (Marx et al. 2003). Overall, the psychometric properties of the study appear promising.

Chapter 4: Can manual wheelchair maintenance program improve wheelchair efficiency and knowledge about wheelchair maintenance, a peer-led feasibility study using a pre-post comparative design

Summary

Manual wheelchair is a common mobility device for people with mobility impairment but users typically receive little, if any training about manual wheelchair maintenance. Running a randomized control trial could generate valuable data about manual wheelchair maintenance but we need more date about wheelchair maintenance training to design and execute a randomized control trial. **Purpose:** The purpose of this feasibility study was to examine whether we were able to run the manual wheelchair-training program and evaluate the feasibility outcomes. **Setting:** Research center with a focus on spinal cord injury and rehabilitation. **Participants:** Five mentors and fifteen mentees were recruited to complete this feasibility study. **Method:**
The main objectives of this study were 1) to evaluate the recruitment capability and report of the sample characteristics, 2) to evaluate the data collection procedures, 3) to evaluate the acceptability of the wheelchair maintenance-training program, 4) to evaluate the resources needed to organize and run the study, 5) to evaluate the participant responses to the interventions. Wheelchair maintenance (intervention) was performed during a peer-session after the baseline visit. The wheelchair maintenance knowledge test, the drag test, self-efficacy test, the 3-cone test, and the 6-minute push test were performed during three visits (baseline, and 2 and 4 weeks after intervention). **Results:** Results from this feasibility study showed we were able to meet our objective goals for data collection. Participants completed all the items and we had

little missing data. Participants did not face any difficulty answering the questionnaires or performing the tests. Therefore, we could conclude data collection was feasible moving forward to perform larger studies. The acceptability of the wheelchair maintenance program was more than 90%. There was a statistically significant improvement in wheelchair maintenance knowledge test and total rolling resistance. Self-confidence of mentees increased after completing the training program. Improvements in the 3-cone test and the 6-minute push test results were not significant. **Conclusions:** If recruitment and scheduling challenges can be overcome, our data suggested that it is feasible to conduct a larger experimental study to test the efficacy of our intervention in manual wheelchair users. The wheelchair maintenance training program was tailored to the manual wheelchair user.

4.1 Introduction

Manual wheelchairs are a common assistive technology used to enhance the mobility of individuals with mobility impairments. The World Health Organization reported that about one percent of the world population uses a wheelchair as their main device for mobility and transportation (World Health Organization, 2008). There are a variety of potential benefits of manual wheelchair maintenance training, (e.g., improved knowledge about manual wheelchair , reduced wheelchair-related accidents) but few manual wheelchair users report receiving wheelchair maintenance training (Nelson et al., 2010; Toro et al., 2017; World Health Organization, 2008).

Wheelchair maintenance may influence the wheelchair users' daily expenses. Ability to maintain the wheelchair would reduce these costs (World Health Organization, 2008). The peer-led wheelchair maintenance training is a community-based intervention that does not rely solely on wheelchair maintenance professionals. With the help of a peer-led program wheelchair users can reduce the wheelchair maintenance cost, which is charged by companies per hour (approx. $75/h) (Wheelin' Mobility, 2017). These companies may charge for monthly membership (between $20 to $60), which can be eliminated with proper wheelchair maintenance training (Cresthealthcare;, 2018; Vogel, 2016).

Wheelchairs that are not well maintained can potentially be dangerous. Often poorly maintained chairs have increased rolling resistance which decreases their mechanical efficiency (Teran & Ueda, 2017), and requires a wheelchair user to use more energy to propel the wheelchair. Overtime this could cause secondary injuries (Cooper et al., 1999; Ummat & Kirby, 1994) (i.e.,

shoulder injury). A randomized control trial study indicated that wheelchair maintenance could decrease the chance of a wheelchair related accidents (Hansen et al., 2004). Although the World Health Organization considered the importance of wheelchair maintenance and suggested routine wheelchair maintenance as an approach to eliminate wheelchair related accidents and improve wheelchair performance (World Health Organization, 2008), wheelchair maintenance training is not commonly available for wheelchair users (Best, Miller, Eng, Routhier, & Goldsmith, 2014; Garber, Bunzel, & Monga, 2002).

Gold standard randomized control trials (Schulz, Altman, & Moher, 2010) could provide valuable information to the clinician and researcher about the effectiveness of wheelchair maintenance training. Developing and conducing a feasibility study is the first step to provide enough information to design a randomized control trial (Orsmond & Cohn, 2015; Thabane et al., 2010). The focus of the feasibility study is to evaluate whether we can conduct a future larger scale randomized trial or not. Feasibility studies are adaptable processes; as studies continue, study procedure and intervention can be modified (Orsmond & Cohn, 2015). The purpose of this feasibility study was to conduct research to examine whether we can develop a randomized control trial. We proposed that conducting a randomized peer-led wheelchair maintenance program is feasible.

Self-efficacy or confidence is an awareness that the individual has about his or her ability to execute a specific behavior to reach a specific outcome. According to Albert Bandura, “self-efficacy is the belief in one’s capabilities to organize and execute the courses of action required

to manage prospective situations" (Bandura, 1997). The Social Cognitive Theory suggests that confidence is the best tool for predicting behavior (Bandura 1997).

High levels of confidence result in consistent achievement and task completion, whereas a low levels may lead to task avoidance (Bandura, 1997). Among the able-bodied population, there is a high correlation between confidence to overcoming barriers to physical activity and participation in new activities (DuCharme & Brawley, 1995; Dzewaltowski, Noble, & Shaw, 1990). Self-efficacy is task specific and evaluate the individual's awareness about his or her capability of performing specific tasks at the particular situation (Bandura, 1997). Measurement of wheelchair related confidence is a new approach in the wheeled mobility field (Rushton, Smith, Miller, & Vaughan, 2017). Confidence that wheelchair users have in their capability to use their wheelchairs is described as wheelchair mobility confidence (Rushton, Miller, Lee Kirby, Eng, & Yip, 2011).

4.2 Study objectives

To evaluate the feasibility of a peer-led wheelchair maintenance program, five feasibility objectives were to evaluate: 1) recruitment capability and sample characteristics, 2) the data collection procedure, 3) the acceptability of the manual wheelchair training program, 4) resources required to implement the wheelchair maintenance training program, and 5) preliminary participants' response to the assessments. These objectives were selected, based on Orsmond and Cohn's feasibility and guidance (Orsmond & Cohn, 2015).

4.3 Method

In this feasibility study, a peer-led model was used as a method to transfer the knowledge from mentors to the mentees about wheelchair maintenance. To conduct this feasibility study, we used a convenience-sampling model. As Figure 4-1 shows, the mentor group received their comprehensive one-day workshop training after signing the consent. Mentees completed the baseline assessments after signing the consent form. Then, they participated in the 3-hour one-on-one peer-session with their mentor (one session only). Mentees completed their second and third assessments 4-weeks and 6-weeks after their peer-session respectively. The template for intervention description and replication use to report this feasibility study (Campbell et al., 2018) (Appendix BB).

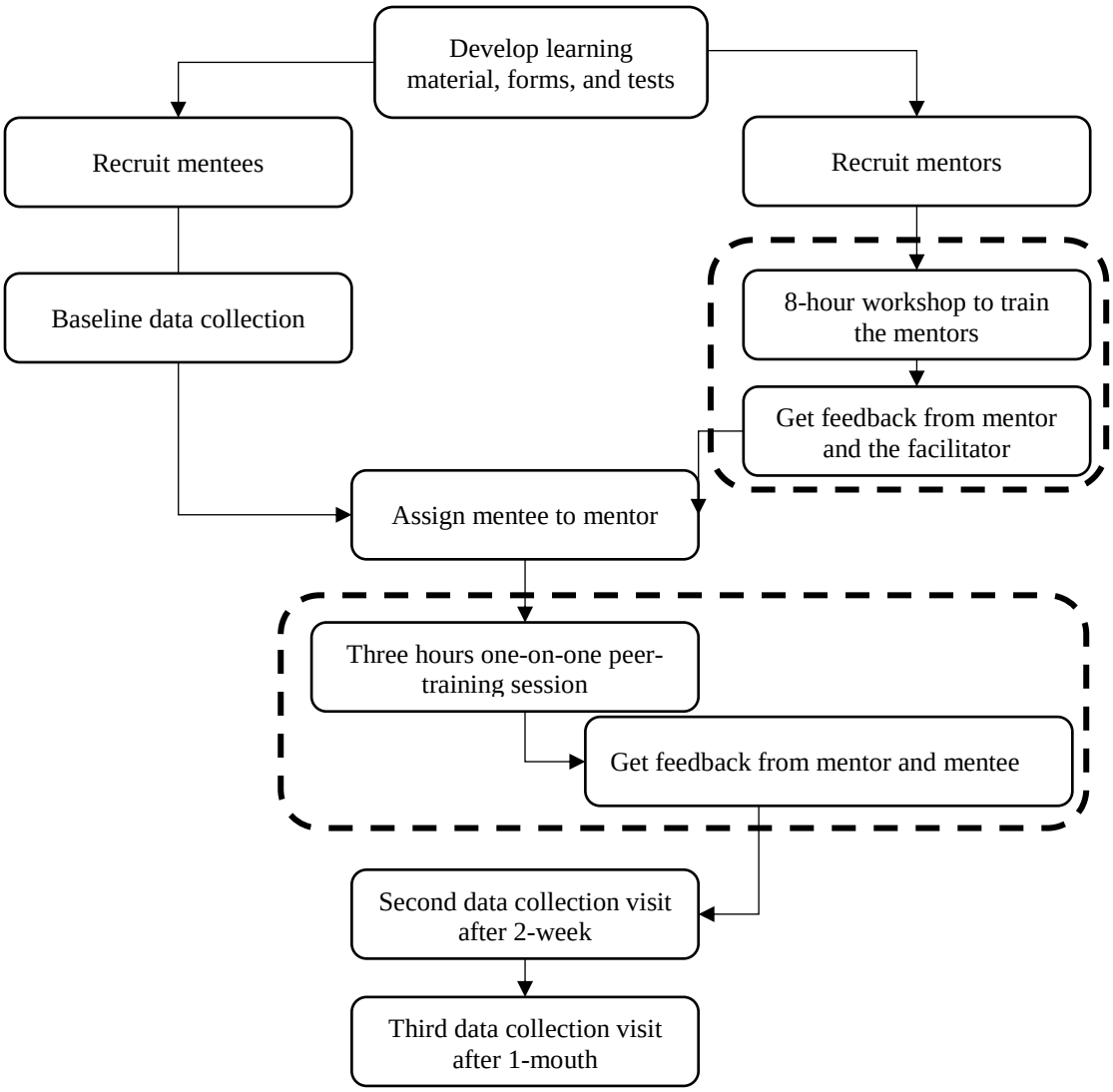

Figure 4-1 Wheelchair maintenance training program proposed design

After enrollment to this feasibility study, participants had to attend several visits over the course of the training program and had to complete the tests and measures. For evaluation of this objective, we recorded all data collection, to report whether the procedure and collected data were complete. Table 4-1 illustrates the feasibility study data collection procedure.

Table 4-1 Can manual wheelchair maintenance program improve wheelchair efficiency and knowledge about wheelchair maintenance, a aeer-led feasibility study using a pre-post comparative design 8 group allocation, descriptive measure, scientific assessments and forms

	Enrolment	Workshop	Baseline ***(Assessment 1)***	Peer-session	Second data collection ***(Assessment 2)***	Last data collection ***(Assessment 3)***
Average days from previous ***(Assessment #)***				**28**	**31**	**16**
Group allocation						
Mentor group (immediate group)	**X**	**X**		**X**		
Mentee group	**X**		**X**	**X**	**X**	**X**
Descriptive measures						
Demographic[6]	**X**					
Scientific Assessments						
Knowledge test[1]			**X**		**X**	**X**
The 3-cone test			**X**		**X**	**X**
Drag test[2]			**X**		**X**	**X**
6MPT[3]			**X**		**X**	**X**
WM Self efficacy[4]			**X**		**X**	**X**
Exit Survey[5]						**X**
Forms						
Workshop evaluation[7] *(By mentor/facilitator)*		**X**				
Peer-session observation[8] *(By researcher)*				**X**		
Peer-session evaluation[9] *(By mentee)*				**X**		
Peer-session evaluation[10] *(By mentor)*				**X**		
KMT form[11] *(By mentee)*			**X**		**X**	**X**

X indicates the test/questionnaire performed.
[1]Wheelchair maintenance knowledge test (Appendi A), [2]The Drag test (de Groot et al. 2007), [3]The 6-minute push test (Callahan, Nash, and Cowan 2011), [4]Wheelchair maintenance self-efficacy (Appendix D), [5]Exit Survey (Appendix I), [6]Demographic forms, [7]Workhop evaluation form (Appendix B, Appendix C), [8]Peer-session observation by researcher (Appendix H), [9]Peer-session evaluation form by mentee (Appendix G), [10]Peer-session valuation by mentor (Appendix F), [11]Knowledge and maintenance track form (Appendix E).

Detailed information for the feasibility outcomes and criteria of success are available in Table 4-2. In this table we assigned feasibility outcomes to the five Orsmond and Cohn's feasibility objectives (Orsmond & Cohn, 2015). We used different tests and questionnaires to evaluate the outcomes and copies of the forms are available in the Appendices of this thesis.

Table 4-2 Detailed description of the measurement for success of the feasibility outcomes

Feasibility outcomes		**Outcome measures**	**Criterion for success**
Evaluation of recruitment capability and sample characteristics	Recruitment rate	# of subject recruited over time	5 mentors in one month 15 mentees in six months
	Participant characteristics		
Evaluation of the data collection procedure	Fidelity	Topic covers during the training	>80%
	Completion rate	Complete the forms and assessments	>80% of measures
Evaluation of the acceptability of the manual	Retention rate	% Of subjects with complete data collection (Three	>80% complete all the sessions

wheelchair training program		assessment visits, one peer-session)	
	Adherence	Attend the scheduled sessions	>80% of subjects attend to 100% of the sessions
	Time management (Scheduling)	Successful scheduling of the peer-led and assessment visit	>80%
	Training Satisfaction	Satisfaction about the wheelchair maintenance training	Results to the exit survey for mentee's satisfaction >90%
Evaluation of the tests to implement the wheelchair maintenance training program	Wheelchair maintenance knowledge test	Improve knowledge about manual wheelchair maintenance	>80%
	The drag test	Decrease in wheelchair total rolling resistance	>5%
	Self-efficacy	Self-efficacy about performing manual	>25%

		wheelchair maintenance	
	The 3-cone test	Improve in wheelchair maneuverability	>5%
	The 6-minute push test	Improve in distance to complete during the test	>5%

Ethics boards of the University of British Columbia approved the study. Below, we present how we approached and evaluated the five feasibility objectives of the wheelchair maintenance-training program.

4.3.1 **"Evaluation of recruitment capability and sample characteristics"**

Recruitment rate and eligibility criteria are evaluated in this objective (Orsmond & Cohn, 2015). In this feasibility study, we proposed to collect data from 15 manual wheelchair users (mentees) within six weeks.

Participants: A total number of 20 wheelchair users with spinal cord disability were recruited on a volunteer basis (mentor=5, mentee=15). The Masters candidate (ME) screened participants for inclusion criteria to confirm that participants: were 19 years of age or older; self-propel manual wheelchairs more than 1 hour per day; are able to attend the peer-session wheelchair

maintenance training; are able to independently transfer from/to a manual wheelchair; and are able to speak and read in English. Individuals were excluded if they were unable to complete the study questionnaire and forms in English; or anticipated health conditions or procedures (e.g., surgery) that contraindicated participation in wheelchair maintenance training. Participation in this feasibility study required a two-month availability; those not able to meet this requirement were excluded from the study.

We did not use criteria based on the type of the injury or disease. Thus, any manual wheelchair user was qualified to participate in this feasibility study. Participants were recruited through advertisements at the International Collaboration On Repair Discoveries, Physical Activity Research Centre and GF-Strong rehabilitation center. If they needed assistance, a participant was permitted to bring their caregiver, helper, friend, or family member to the study.

4.3.2 **"Evaluation of the data collection procedure"**

To evaluate and report this goal, we recorded the *fidelity* and *completion rate* of the wheelchair maintenance feasibility study. We were interested in the number of topics and number of surveys and questionnaires, completed through the feasibility study (Orsmond & Cohn, 2015; Thabane et al., 2010).

Procedure: The Masters candidate (ME) and two primary investigators (BS, BM) personally invited the mentors (five participants) to participate in this feasibility study. After mentors signed their consent forms, each one was assigned a unique study identification code. Mentors received focused training on wheelchair maintenance at a one-day (8-hour) wheelchair maintenance

workshop. This training covered information about the tools needed to perform wheelchair maintenance, and performing wheelchair maintenance, as well as cleaning and lubrication of a manual wheelchair. Mr. Ian Denison, an equipment specialist, managed and taught the workshop to the mentors while the Masters candidate (ME), both principal investigators (BS, WM), and four volunteers helped as facilitators. Ian Denison has worked as a physiotherapist and equipment specialist at GF Strong Rehabilitation Centre in Vancouver, Canada, since 1980. Each mentor was provided with an updated version of the manual wheelchair maintenance training series (Denison, 2016) and a complete set of wheelchair maintenance tools (worth about $200). These included a 144-piece toolbox, adjustable wrench, rubber hammer, tape measure, air pump, tire lever, and cleaning supplies. Mentors kept the tool set after finishing their participation in the workshop and the rest of this study.

Matching mentor to mentee for one-on-one peer-sessions (scheduling): Upon recruitment, each mentee signed an informed consent form. Each mentee was assigned to one mentor with whom they were to have a one-on-one peer training session (3-hour). Each mentor had three mentees. In advance of each peer-session, the mentee shared a topic of interest in wheelchair maintenance (based on wheelchair maintenance training program syllabus). The Masters candidate informed the mentor of the topic before the peer-training session so that they could prepare, in advance, the peer-session based on mentee's request. The mentor and Masters candidate (ME) for each peer-session prepared tools and equipment. Different types of wheelchair parts and tools were brought to the peer-session including the videos from www.iwheel.ca. Both mentor and mentees evaluated the sessions. The Masters candidate

observed all peer-sessions (fifteen one-on-one peer-sessions) and completed the observation form (Appendix H).

In addition to attending the peer-session, each mentee completed three assessment sessions. The baseline assessment was held before the peer-session and two post assessments were completed four-weeks and six-weeks after the peer-session. Participants completed the wheelchair maintenance knowledge test, the drag test, the 3-cone test and the 6-minute push test during each assessment session. At the end of each session, they also completed the knowledge and maintenance track form (Appendix E). We also asked them to complete the self-confidence questionnaire before and after the wheelchair maintenance program, as well as an exit survey. In total, each mentee was expected to complete 19 tests, questionnaires, and forms. We used the I-Wheel checklist (Appendix J) to track the activity of each participant throughout his or her participation in the study.

4.3.3 **"Evaluation of the acceptability of the manual wheelchair training program"**

Retention rate, adherence, time management (scheduling) and *training satisfaction* were measured to evaluate the acceptability of this feasibility study. The Masters candidate (ME) observed and recorded all the sessions (i.e., scheduled, re-scheduled, and canceled) of this feasibility study. We measured training satisfaction through the feedback from mentees at the end of the wheelchair maintenance-training program.

Each mentee completed the mentee exit survey at the end of wheelchair training program. The mentee answered questions about their wheelchair (model, brand, price, etc.) and questions about

the wheelchair-training program. Five questions of the exit survey asked about the participant satisfaction, which uses a 5-point scale (5=very good to 1=poor), resulting a final score between 5 and 25). Data from the exit survey were recorded and summarized to report the total training satisfaction.

4.3.4 **"Evaluation of the resources to implement the wheelchair maintenance training program"**

The main question of this objective was whether the research team has adequate qualifications and expertise to perform the study and interventions. Another question was about the space we used to conduct this feasibility study. We wanted to know if our lab space would satisfy the requirement for this feasibility study. Finally, we evaluated the online data management system (*Global Research Platform*), and website (*www.iwheel.ca*) which were used to improve the quality of this feasibility study. Benchmark of success for the management system: to be able to perform wheelchair maintenance knowledge test without any missing data, score them automatically and export the result to Excel file. Benchmark of success for the website: to be able to post the training manual and videos to the website, to be able to reach the uploaded training content 24/7 and from any type of device (Personal computer, tablet and cell-phone).

4.3.5 **"Evaluation of the participant response to the assessments"**

Each mentee completed the wheelchair maintenance knowledge test, the drag test, the 3-cone test, and the 6-minute push test during their 3-assessment visits. The Masters candidate (ME) recorded the tire pressure at the beginning of each assessment visit. They also completed the self-

efficacy questionnaire at the baseline and at the last assessment visits. All the participants completed the exit survey during their last assessments and answered questions about the program satisfaction. Table 4-3 presents the group allocations, forms and scientific assessment, which were completed during each visit by the participants and the Masters candidate (ME).

The wheelchair maintenance knowledge test measures the knowledge of participants regarding manual wheelchair maintenance. It includes 35 items. There is only one correct answer per question and participants received one point if they chose the right answer. There is no time limitation to answer the questions. Respondents were asked to choose “do not know” if they are not sure about the answers. Report of absolute and relative reliability of the wheelchair maintenance is available in Chapter 3. To perform the wheelchair maintenance knowledge test, participants answered 35-multiple questions during each assessment visit (three visits). We asked participants to answer to all the questions and select “don’t know” if they were not sure about the answer.

The drag test is an established test to measure the total rolling resistance of the manual wheelchair (de Groot et al., 2007; van der Woude et al., 2006). Wheelchair maintenance is an important component of wheelchair efficiency (Hansen et al., 2004) and the drag test is a well-established test to evaluate the manual wheelchair efficiency in the clinical and research settings (Chan et al., 2017; de Groot et al., 2007). A wheelchair with lower rolling resistance has higher overall mechanical efficiency (Zepeda et al., 2016). To perform the drag test, we secured the participant’s wheelchair to the force transducer, which was located on the treadmill (speed 1.1m/s) and asked the participant to sit passively on the wheelchair during the test. Weight

distribution is an important factor of the measuring total rolling resistance (Zepeda et al., 2016) and we made sure participants had the same weight distribution during all data collection visits.

As no measure was available to measure confidence with manual wheelchair maintenance we developed our own study specific measure. We drew on the existing Wheelchair Use Confidence Scale for manual wheelchair users (Rushton et al., 2011) to develop the questionnaire for manual wheelchair maintenance confidence. This self-report questionnaire has two sections. The first section had 7 questions with which wheelchair users rated their confidence performing different manual wheelchair maintenance task. In the second section, which has 7 questions, wheelchair users rate their confidence in teaching manual wheelchair maintenance skills to others. To complete this questionnaire, participants used a 100-point response scale from 0 (not confident) to 100 (completely confident) for each item. Final results reported in percentage.

Participants completed the questionnaire (Appendix D) at the baseline and after they completed their last (third) assessment visit. The Masters candidate read the questions and instructions to make sure participants understood all the questions. We asked participants to answer to all the questions. Results from these two assessments are available at Appendix O and Appendix P. All of our participants were able to complete the questionnaire without any help.

The 3-cone test was developed to evaluate the manual wheelchair maneuverability. This test has an excellent relative reliability index (intra-class correlation coefficient > 0.90). Maintaining the manual wheelchair's front casters and their bearing, which are responsible for the wheelchair maneuverability, is one of the most important parts of the wheelchair maintenance program. We

used this test to see the result of performing a wheelchair maintenance on the wheelchair maneuverability.

Participants performed the 3-cone test during assessment visits (three times). They performed three trials during each visit and we considered the first two trials as a training or practice trial and used the last trial for the data analysis. Participants were allowed to take a break between the trials. We asked participants to not perform moderate to hard exercise the day of data collection.

The 6-minute push test is a reliable test (>0.84) and measures the aerobic capacity of the wheelchair user (Cowan et al., 2012). We assumed aerobic capacity of the wheelchair user was not going to change during this study and any change in the result of the 6-minute push test occurs as a result of wheelchair maintenance. To perform the 6-minute push test we gave the participant up to 10 minutes of recovery time if they had just performed other physical tests so that they may return to baseline status. All participants wheeled around the outlined green dotted track for the 6-minute test (each lap was 39 meters). During the test we asked participants to keep the green dotted tape underneath themselves at all times; in other words, participants should be straddling the line by keeping one wheel on either side of it at all times. During the six minutes, participant could take as many breaks as they like. However, the clock kept running. The distance (in meters) was recorded at the end of the trial.

4.4 **Statistical analysis**

The data collected were analyzed for feasibility outcomes. Participants performed all the tests and questionnaires in person during three assessments and one peer-session visit (total for four

visits). All the data were inputted in password protected files and primary investigators checked the data entry procedure for accuracy. Descriptive statistics (e.g., means, frequencies, proportions, and standard deviations) were used to present feasibility results.

To evaluate the recruitment capability and sample characteristics, the *recruitment rate* was considered the percentage of individuals who agreed to participate as a mentor/mentee. To determine the evaluation of the data collection procedure we examined the *fidelity* of intervention and completion of outcome measures. We expected mentors follow the wheelchair maintenance training manual topics during the peer-session. All the responses from the participants were used to calculate the *completion rate*. We reported the number of forms completed by participants, the Masters candidate, or the workshop facilitator during the wheelchair maintenance program and calculated the percentage of the completed forms to report the *completion rate*.

To understand the acceptability of the program we calculated the retention rate, which represented the training program and the percentage of dropout participants for mentor/mentee. The percentage of sessions attended was calculated to determine *adherence* and this included the number of sessions and workshops that participants completed to measure the adherence of the training program. To evaluate the resources needed to implement the wheelchair maintenance training program we focused on the time management (scheduling), by recording all the visits (Appendix K). We counted and recorded all the cancellations and rescheduling. We reported the scheduling and attendance results.

Evaluation of participant response to the assessment was based on the satisfaction of the wheelchair maintenance training program. This was calculated using the mentee *satisfaction* rate from the mentee exit survey (Appendix Q). The percentage of satisfaction about the peer-sessions, satisfaction about mentor's knowledge, satisfaction about components of the training program, satisfaction about availability of learning material, and satisfaction about tools and maintenance, were calculated to report the acceptability of the wheelchair maintenance program. The average of these five-acceptability components was calculated and reported as total satisfaction of this program.

One-way repeated measures ANOVA was performed to determine whether the difference between means were statistically significant. Since assessment for self-efficacy was only performed two times (pre-post), we conducted the paired t-test to determine whether change in self-efficacy was statistically significant. **The Wheelchair Maintenance Knowledge Test:** We measured change in participants' score on the wheelchair maintenance knowledge test at the baseline visit, and two-weeks, and six-weeks after peer-session training. **The Drag test:** We measured change in the total rolling resistance of the participant's manual wheelchair based on the treadmill drag test force (N) at the baseline visit, and two-weeks and 6-weeks after peer-session training. We recorded the tire pressure at each visit and averaged the left and right tire. We performed a correlation statistic between tire pressure and the drag test results. **Self-confidence:** We measured the change in wheelchair maintenance confidence of the participant at the baseline visit and post training (6-weeks after peer-session training). A paired t-test was performed to detect any statistical differences between before and after the wheelchair maintenance-training program and a bar chart graph was used to present the change visually.

The 3-cone test: We measured the change in wheelchair maneuverability performance based on results from the 3-cone test (seconds) at the baseline visit, and 2-weeks and 4-weeks after peer session training. We used a similar method to that reported in chapter 2 for data collection and trial selection. **The 6-minute push test:** We measured the change in wheelchair users' total performance-based distance measured (m) on the 6-minute push test, which recorded at the baseline visit, and 2-weeks and 4-weeks after peer session training.

4.5 Results

4.5.1 "Evaluation of recruitment capability and sample characteristics"

We found that recruiting participants for the wheelchair maintenance training was challenging. The participants' demographic information is presented in Table 4-3Twenty percent of both groups were female. The majority of participants had spinal cord injuries and spent more than 10 hours a day in their manual wheelchair. We had more males recruited in the study and enrolled some females to add diversity to our sample characteristics. Mentors had a lower age of injury and spent more time in their wheelchair during the day, which gave them more experience using a wheelchair.

Mentors recruitment rate: Over the course of one month, we contacted seven experienced wheelchair users to participate in our study as a mentor. Five (71%) agreed to be part of this peer-led study. The time commitment was the only reason for not participating in the study.

Mentee recruitment rate: Physical Activity Research Center was the main recruitment site for our study. All the members agreed to be contacted about participating in the research studies. At the time of recruitment, Physical Activity Research Center had 192 members. Out of 192

members, 60 wheelchair users agreed to be contacted about the wheelchair maintenance program and 15 (25%) agreed to participate in the study as a mentee (It took 6 months to complete, Appendix V). We recorded the reasons used by 45 (75%) as to why they did not participate in our study (Appendix X). Each mentor worked with three mentee and we matched them based on their time availability.

Table 4-3 Demographic table

Variable	Mean ± SD (Range) / N (%)	
	Mentor n =5	***Mentee*** n =15
Age (Y)	46 ± 7.8 (34-53)	51.07 ± 11.83 (32-71)
Sex		
Male	4 (80%)	12 (80%)
Height (cm)	173 ± 10.72 (155-183)	169.77 ± 11.35 (155-187)
Weight (kg)	80.53 ± 17.95 (65-114)	80.61 ± 16.02 (47-108)
Education		
High school	0 (0%)	1 (6.5%)
College diploma	3 (60%)	7 (47%)
University degree	0 (0%)	3 (20%)
Graduate studies	2 (40%)	1 (6.5%)
Post graduate	0 (0%)	3 (20%)
Length of wheelchair use (Y)	22.17 ± 12.36 (2-33)	15.17 ± 13.03 (2-38)
Age of injury (Y)	23.83 ± 13.00 (16-50)	30.60 ± 20.12 (0-55)
Diagnosis of wheelchair users		
Spinal cord injury	5 (100%)	11 (73%)
Spina Bifida	0 (0%)	1 (6.5%)
Multiple Sclerosis	0 (0%)	2 (14%)
Polio	0 (0%)	1 (6.5%)
Hours of wheelchair use per day	13.33 ± 4.89	10.40 ± 5.59
How often do maintenance		
Never	0 (0%)	4 (27%)
Weekly	0 (0%)	0 (0%)
Monthly	3 (60%)	2 (13%)
Every 3-month	1 (20%)	5 (33%)
Every 6-month	0 (0%)	4 (27%)
Yearly	1 (20%)	0 (0%)

4.5.2 **"Evaluation of the data collection procedure"**

Fidelity: Eight topics were covered in our wheelchair maintenance syllabus. Table 4-4 presents a summary of topics and tasks completed during the peer-session training. Excepting three topics (bearings, wheel lock, toeing error), we could not complete all the topics during a peer-session. Detailed result of peer-session training available in Appendix Y.

Table 4-4 Topic covered during peer-training session (fidelity)

Time spent and task complete	N (%) (N_{mentee}=15)
1. Tools & suggested supplement	12 (80%)
2. Bearings	15 (100%)
3. Wheel lock	15 (100%)
4. Toeing error	15 (100%)
5. Caster stem	14 (94%)
6. Cleaning	8 (53%)
7. Lubrication	9 (60%)
8. Tires	6 (40%)

Completion rate: In total, mentors, mentees, the workshop facilitator, and the Masters candidate completed 388 forms, questionnaires, and tests to complete the wheelchair maintenance training program. Only two questionnaires were not completed by the mentees. Table 4-5 shows the number of forms, questionnaires and tests in detail.

Table 4-5 Total number of forms, questionnaires and tests completed in this feasibility study

Completed by	$N_{completed}$ / $N_{need\ to\ omplete}$ (%)
1. Mentor	40 / 40 (100%)
2. Mentee	283/ 285 (99.3%)
3. Workshop facilitator	5/ 5 (100%)
4. Masters candidate	30/ 30 (100%)
Total	388/ 390 (99.3%)

Note about data quality: There was no missing data recorded for the questionnaires and wheelchair knowledge test.

4.5.3 **"Evaluation of the acceptability of the manual wheelchair training program"**

Results from the *Retention rate*, *Adherence*, *Time management* and *Training satisfaction* were reported to express the acceptability of the manual wheelchair maintenance training.

***Retention rate*:** From the beginning, we were conservative about the time commitment and process of the study and detailed this on the participant's consent form. We also explained these details during their consent visit, so they had a clear understanding about the study. Fortunately, we did not have any dropouts.

***Adherence*:** Participants were able to complete all the scheduled sessions for this feasibility study. In total, fifteen peer-sessions, one full-day workshop, and forty-five assessment completed. If any session or assessment was canceled (by mentor or mentee), we rescheduled the session/assessment. In general, scheduling assessments was easier because we only dealt with the mentee. However, scheduling peer-sessions required that we get confirmation from both mentor and mentee and sometimes finding a convenient time was challenging. As Table 4-6 shows, we had the most cancellations (87%) for the peer-session visits and cancellations for all the assessment days were less than 33%.

Table 4-6 Number performed and rescheduled sessions

	1st assessment N (%)	Peer-session N (%)	2nd assessment N (%)	3rd assessment N (%)	Total N (%)
Session performed	15	15	15	15	60
Session /rescheduled	5 (33%)	13 (87%)	5 (33%)	4 (27%)	28 (47%)

Note. Percentage was calculated based on performed sessions

***Time Management (Scheduling)*:** Although we were able to complete all of the wheelchair maintenance training program visits, we were unable to follow the expected timeline (i.e., days between assessments) that we defined for this feasibility study (success rate >80%). We planned to schedule the peer-led session one week after the baseline assessment, but we could not reach our goal. Table 4-7 presents the proposed days for each assessment and the actual days between sessions.

Table 4-7 Days between assessments (proposed and performed)

Timeline [days]	**Days in Between Assessments**		
	Baseline to peer-session	**Peer-session to 2nd assessment**	**2nd to 3rd assessment**
Expected	7	7	30
Actual	28	31	16

Total training satisfaction: The wheelchair maintenance-training program included five main components. Minimum score for each component is 5 and maximum is 25. Results for each component was calculated by dividing the total score for each component by 25 (the maximum) and multiplying by 100. The total satisfaction is the average of five components. As Table 4-8 shows, total satisfaction for this program was 91%.

Table 4-8 Satisfaction about wheelchair maintenance program

Satisfaction about peer-session	Satisfaction about mentor's knowledge	Satisfaction about component of training program	Satisfaction about availability of learning material	Satisfaction about tools and maintenance	Total satisfaction
89%	91%	87%	94%	93%	91%

4.5.4 "Evaluation of the resources to implement the wheelchair maintenance training program"

The Masters candidate (ME), two principal investigators and the equipment specialist who consulted and helped the research team through this feasibility study were involved in the trainer workshops. We had enough space in our research center to answer all needs for this feasibility study.

The *Global Research Platform* has a feature to detect the missing data as the participant enters data. We did not miss any data while participants answered the questionnaires because of using the *Global Research Platform* (Rick Hansen Institute 2011). Participants were able to use a mouse (if they use a computer) or their finger (if they use a tablet) to answer questionnaires and we received positive feedback from those wheelchair users who had limited hand function. Another online tool was our website (*www.iwheel.ca*), which was used to make all the training materials such as videos and manuals available to all the participants. Our website worked without any problem on all the platforms (i.e., desktop and portable devices) and participants were able to reach the learning materials from anywhere with internet access. Since some of

resources were provided to us for free and we paid for few of them (website, tools and the equipment specialist), it was hard to calculate a cost to deliver the interventions to participants.

4.5.5 **"Evaluation of the participant response to the assessments"**

To assess whether the peer-led session (wheelchair maintenance intervention) shows promise of being successful in manual wheelchair users, we evaluated the results of the assessments at baseline, and two and six weeks after peer-led session. Results for each test reports as below:

Wheelchair maintenance knowledge test: Results from the wheelchair maintenance test are available in Appendix R. Our results showed that the mean total for knowledge about wheelchair maintenance increased from 14.6 ± 4.99 to 22.0 ± 3.70 (95% CI). The repeated measures ANOVA indicated that there was a significant difference between results over time (baseline mean score=14.67 ± 4.99, second and third assessments mean score=22.0 ± 3.70). A pairwise comparison (adjustment for multiple comparisons: Bonferroni) revealed that wheelchair maintenance training elicited an increase in knowledge test result from a pre-training (baseline) to post training (two and six weeks after intervention). Results for wheelchair maintenance knowledge tests are available in Appendix R.

The drag test: The results for the rolling resistance are available in Appendix U. Repeated measures ANOVA indicated that there was a statistical difference between the assessment results. The Pairwise comparison (Adjustment for multiple comparisons: Bonferroni) showed that the results from the second assessment (2 weeks after the peer-session) were statistically

different from the two other assessments (baseline and 6-weeks after intervention). The results from the drag test are summarized in figure 4-2.

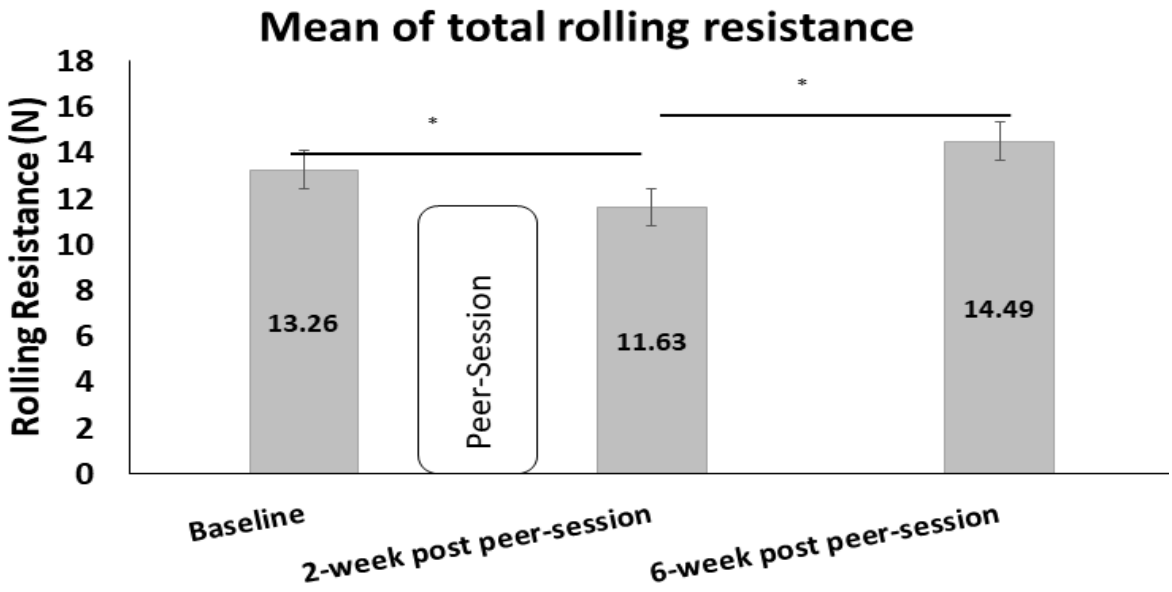

Figure 4-2 Total rolling resistance

Results from tire pressure recording indicated that 4 (27%) of our participants had manual wheelchairs with solid tires and there was low, negative correlation between tire pressure and total rolling resistance (r= -.276). Repeated measure ANOVA results indicated there was significant difference between baseline and 6-weeks after peer-session visits. Figure 4-3 illustrates the change in mean tire pressure recorded during assessments.

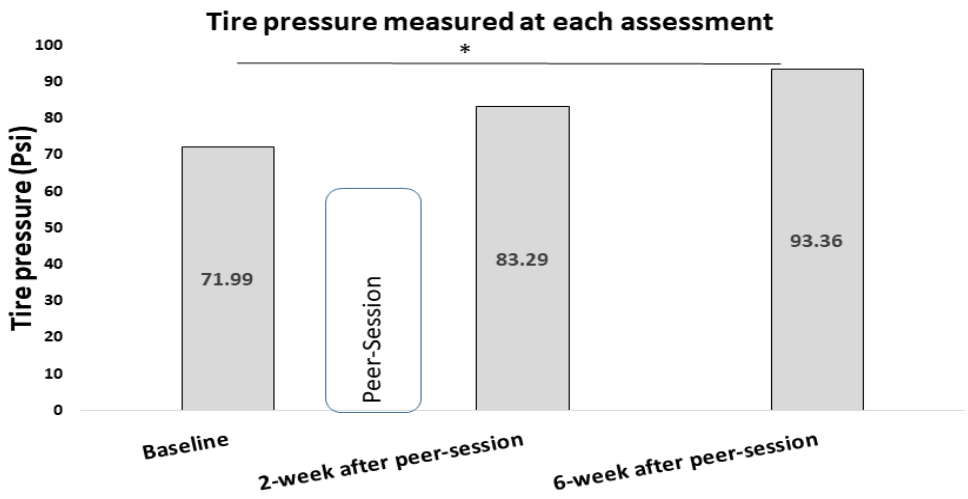

Figure 4-3 Mean tire pressure during assessment visits.

Self-confidence: Results from each participant was calculated and added as a final score for them. Final score for performing wheelchair maintenance and confidence in teaching were recorded at baseline (50.25 ± 31.62; 44.07 ± 31.34) and post-wheelchair maintenance training (85.17 ± 17.23; 77.09 ± 19.75). To evaluate the changes during the wheelchair maintenance training program, a paired sample t-test was performed ($p<.001$). T-test results indicated that the post self-confidence mean was statistically significantly higher than the baseline self-confidence means. A graphical representation of the means and 95% confidence intervals is illustrated in Figure 4-4. Confidence in performing or teaching wheelchair maintenance related activities increased from 50% to 85% after the wheelchair maintenance program.

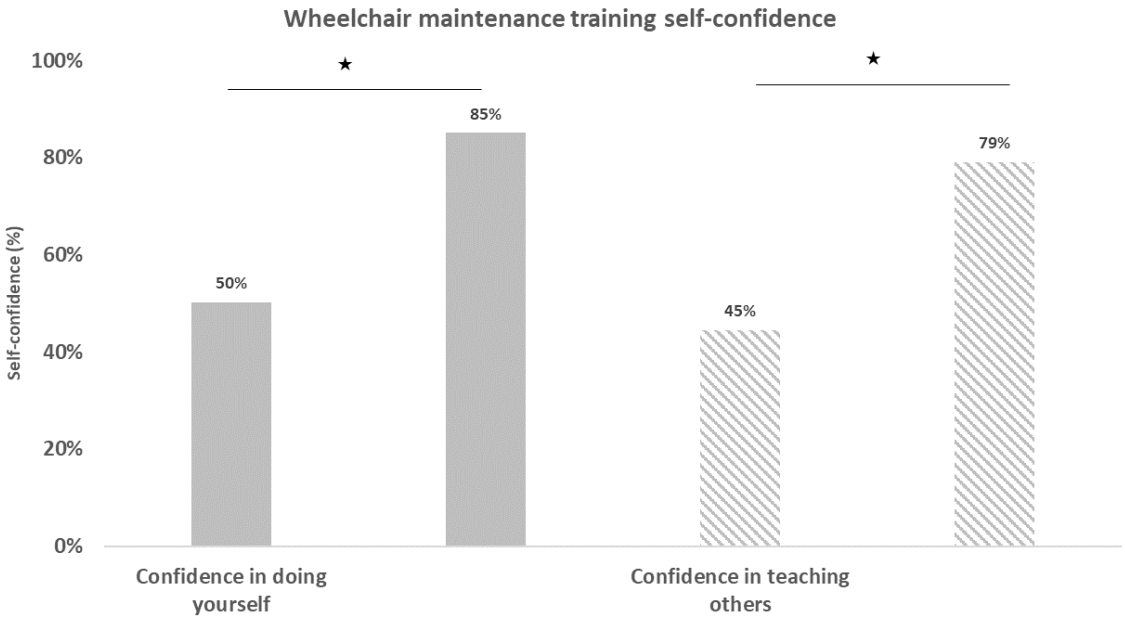

Figure 4-4 Self-confidence, and 95% CIs associated with the baseline and post-training conditions

The 3-cone test: The results for all the trials of the 3-cone test are available in Appendix S. The results showed that there was no statistically significant difference between the three assessment days. However, the mean of the 3-cone test decreased by 1.2 seconds (6%) and did not change during the third assessment (Figure 4-5).

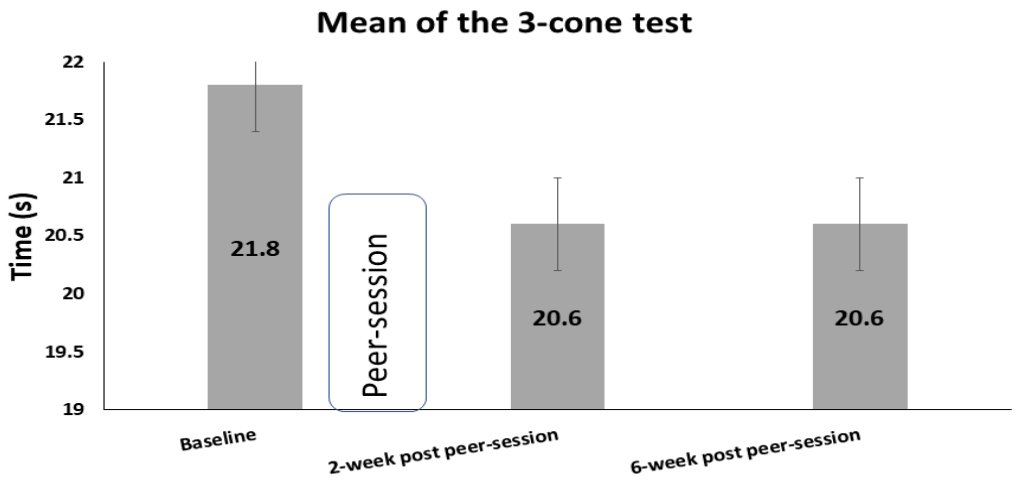

Figure 4-5 Mean results for the 3-cone test

The 6-minute push test: The mean and standard deviation for the 6-minute push test during three assessments and It was concluded that there is no significant difference in means. In another word a repeated measure ANOVA showed there was no statistically significant difference between the three assessments. Detailed results for the 6-minute push test are available in Appendix T.

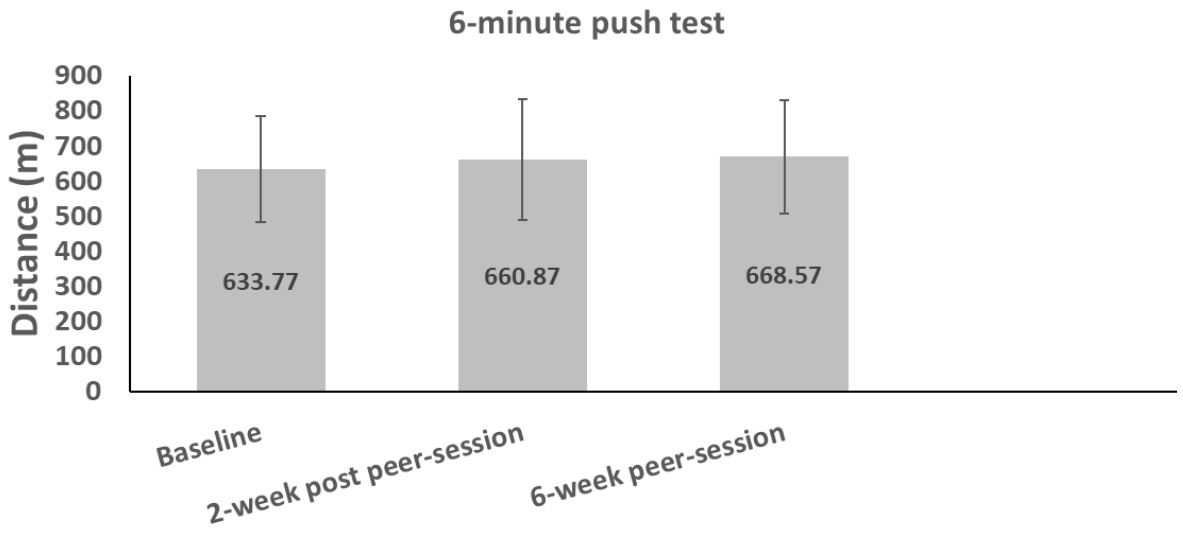

Figure 4-6 Mean results for the 6-minute push test

4.6 Discussion

There is a dearth of literature on manual wheelchair maintenance training (World Health Organization, 2013c). To our knowledge, this is the first feasibility study to develop and evaluate a wheelchair maintenance study focused on training of wheelchair users. We organized the discussion section based on the study objectives.

4.6.1 "Evaluation of recruitment capability and sample characteristics"

Overall, we found that recruitment was challenging but feasible. We were able to meet our recruitment goal in the predicted time frame (mentors: one month, mentees: four months) however it took longer than what we anticipated. To facilitate recruitment, we decided to include spinal cord disease population. We suggest using the same inclusion criteria (any manual wheelchair user) to design and perform future randomized control trials.

The demographic characteristics of our participants were very similar to the reported sample in other wheelchair skill training studies (Best et al., 2005). The range of age for the included participants, mentors and mentees, were from middle age to older adult. We know that the average age of wheelchair users is increasing and there is a need to study older populations in the future (Karmarkar et al., 2011).

4.6.2 **"Evaluation of the data collection procedure"**

We were able to meet our objective goals for data collection. Participants completed all the items and we had little missing data. Therefore, we could conclude data collection was feasible moving forward to perform larger studies. In our study, we used newly developed questionnaires and tests. However, participants did not face any difficulty answering the questionnaires or performing the tests. Using theses questionnaires or tests in future studies needs to be done with more caution.

4.6.3 **"Evaluation of the acceptability of the manual wheelchair training program"**

Based on our metrics the wheelchair maintenance training program appeared acceptable participants had no problems with the acceptability of the program's underlying message; learning material, format that material presented. However, it was challenging to schedule appointments when mentors and mentees both needed to be present for the peer sessions. Individual time availability was the main factor affecting scheduling participants for peer sessions. Initially we tried to randomly match mentors and mentees, but it did not work. Therefore, we changed our strategy and we used doodle poll system to record the time

availability of both mentor and mentees. This matching model needs more work and stakeholder consultation might help develop the matching method in larger studies.

4.6.4 **"Evaluation of the resources to implement the wheelchair maintenance training program"**

Despite the relatively modest study budget, we were able to implement the wheelchair maintenance program with the resources available. The data management system could facilitate the data collection, storing and scoring in larger studies. We developed online resources for training materials and participants were able to reach the content without (training manual and videos) any problem Online training has a potential to be part of larger studies. However, using a web developer can improve the quality of the website. Online features, such as online scheduling on calendar can be part of the website designed and implemented by web developer to facilitate the study scheduling. Tools were essential for this training program. Limited funding was a challenge to be able to provide more resources such as more tools for all participants, but free tools were provided to each mentor. Preparing more tools can be beneficial to perform larger studies. More funding and resources will make the wheelchair maintenance training sustainable.

4.6.5 **"Evaluation of the participant response to the assessments"**

In our feasibility study, we were able to get a high response rate from our participants by providing consistent follow-ups for participation, providing free resources for participants, flexibility of assessment time, and availability of online and in person learning materials. Our finding supports the idea of participants putting their knowledge into practice by the end of the training program.

Evaluation of the quantitative results from all tests, except the-3-cone test and 6-minute push test was promising. Using the 3-cone test and the 6-minute push test in future studies needs to be done with more caution. We Results front the drag test showed there was a significant improvement in total rolling resistance over time but returned to baseline trending in the opposite direction over time. One of the possible explanations to this change is change in tire pressure over time. We expected to see a positive correlation between tire pressure and total rolling resistance. However, our results did not support this assumption. The trends for the total rolling resistance and tire pressure were different. However, more research needs to be done to have better understanding of the relation between tire pressure and the total rolling resistance.

4.7 Conclusion

With the increased demand for providing evidence based medicine in research (Green & Britten, 1998) and guidelines to report randomized control trials (Schulz et al., 2010), there is a need to develop and present more feasibility studies (Orsmond & Cohn, 2015) to develop enough data to design the randomized control trial. Using more structured framework to conduct feasibility studies may improve the quality of the feasibility outcomes and help conduct gold standard randomized control trials (Eldridge et al., 2016; Thabane et al., 2010).

This feasibility study covered basic wheelchair maintenance skills. This novel approach may alleviate clinical burden, especially with regard to progressive training in advanced manual wheelchair maintenance skills. All mentees perfectly completed three data collection sessions and one one-on-one peer-training session with their assigned mentors. Results from the exit

survey showed a high training satisfaction from mentees, which translates to participating in the training program and performing the wheelchair maintenance. The feasibility outcomes of this feasibility study were promising for creating large randomized control trials.

Although this study showed completion of training by peer mentorship design, coordination with both mentors and mentees by a research coordinator (Graduate student in this study) was inevitable. Thus, moving forward to the RCT phase, we need coordinators to guide for mentors and mentees during each session. Scheduling was managed by graduate student in this study. However, RCT with more study participants requires scheduling management tools. Additionally, we provided tools to mentors in this study. To be ideal, tools should be provided to both mentors and mentees. All these expenses should be considered and planned before the RCT design. To conclude, findings of this study have potentials for developing to RCT. However, all documented considerations should be implemented before further steps.

4.8 Future direction

In a future experimental study, we suggest investigating whether the wheelchair maintenance training program resulted in a reduction in wheelchair repairs and the related consequences. We can use the feasibility and scientific results from this study to develop a randomize control trial in the future. We suggest providing two different wheelchair maintenance-training programs. The first program would include only the maintenance training by lecture, and the second program would include two lectures and a hands-on training session. Subsequent training would then be used as an intervention technique and participants would be randomly selected to receive

the training in different sequences. Scientific results supported all the hypotheses except the 3-cone test and the 6-minute push test. These tests may not be appropriate to for future evaluations.

Needed time for the peer-session could be different for each participant and the goal is to cover all the training topics during the session. Not all topics could be covered during one peer-session. A possible solution to address covering all topics in a peer-session is to have additional peer-sessions, but as the adherence rate showed, the cancellation rate for the peer-sessions was high (87%). It may be more practical to schedule a longer session (longer than 3 hours) with two or three breaks in between. Acceptability of the study through the questions needs to be assessed more by adding open-ended questions and interviews.

4.9 Study limitation

This study has two main limitations. First, small sample size (n=15) was the main limitation of this study but we believe the results from this study can be used to provide information for development of a randomized control trail for manual wheelchair maintenance. Second, we did not have a control group in our study. Adding a control group in the future may increase the validity of the results.

Chapter 5: Conclusion

5.1 Summary

Despite the increase in the number of manual wheelchair users (Government of Canada, 2010), there is limited evidence available on wheelchair maintenance training and most of the literature is focused on other aspects of wheelchair such as wheelchair skills. Wheelchair users and their wheelchair should be considered as a unit from the beginning after their injury. However, the emphasis in the literature has been on skills and also biomechanics (human and wheelchair interface)., little attention has been on the actual wheelchair itself and its maintenance over time. Programs have been developed for people to get stronger to use the wheelchair or learn skills to get around better but what about programs to keep the wheelchair going? Is this the responsibility of the user or just the provider?

Wheelchair maintenance has an important role in preventing many overuse physical injuries in this population and subsequently decrease the burden on healthcare system (Hansen et al., 2004). To our knowledge, there is no accessible and affordable program available for manual wheelchair users to maintain their wheelchairs. Development of a peer mentoring program to teach wheelchair maintenance skills would be beneficial to improve the current lack of training programs. Additionally, there is no well-developed and reliable wheeling maneuverability and wheelchair maintenance knowledge test available for researchers and clinicians to evaluate their participants or patients. This study aimed to deliver the knowledge to the wheelchair user through a peer mentoring model.

Over the course of this thesis, we first developed the 3-cone test and the wheelchair maintenance knowledge test to evaluate manual wheelchair maneuverability and examine knowledge regarding wheelchair maintenance. Comparison of the lower bound of the 95% confidence interval of the measurements and minimum detectable change of these two tests showed the wheelchair maintenance knowledge test can differentiate the wheelchair user and novice able bodied from each other. However, the detectable change in the 3-cone test might be the result of the measurement error and should be interpreted with caution.

Although not described above, the responsiveness of these newly developed measures and the wheelchair maintenance confidence test are reported in Appendix CC. Responsiveness is defined as the power of a measure to discover important change over time (Guyatt, Kirshner, & Jaeschke, 1992). Standardized response mean (SRM) is commonly used to report the responsiveness of the findings in research (Walters & Brazier, 2003). The SRM is defined as the mean change in scores between the baseline and the follow-up visit divided by the standard deviation of the change scores (Heart and Stroke foundation, 2018).The findings of this study indicate that the corresponding SRM of wheelchair maintenance knowledge test (SRM= 1.85) and the self-confidence ($SRM_{doing\ yourself}$ = 1.43, $SRM_{teaching\ others}$ =1.80) were in the “large” range using Cohen’s criteria (Luiz & Almeida, 2012; Walters & Brazier, 2003). The SRM for the 3-cone test (-0.56) would be considered “small to moderate.” Thus, the wheelchair maintenance knowledge test and the self-confidence self-report demonstrate better responsiveness to the intervention.

To complete this thesis, we used both wheelchair user and novice able-bodied population to complete the 3-cone and wheelchair maintenance knowledge test. However, it should be

acknowledged that wheelchair user and novice able-bodied experience different physical barriers when they use a manual wheelchair (Reid, 1999). The 3-cone test requires physical activity and able-bodied surrogates will not experience the same issues as wheelchair users in terms of and physical barriers such as trunk movement or range of movement. This likely is reflected in findings by Kirby et al., that showed there is a statistically different between wheelchair users and novice able-bodied population to complete the wheelchair skill test, indoor skill and community skill (Kirby et al., 2005). These differences may affect the extreme-group validity; hence there are questions about the generalizability of the findings to novice wheelchair users. The physical differences between the wheelchair users and novice able-bodied individuals is likely less relevant with wheelchair maintenance knowledge test, since this required minimal physical activity to complete this test. However, wheelchair users may have been more motivated to acquire new knowledge to be able to respond to questions they did not know the answers to on the second administration, which could contribute to a learning effect.

In addition to the 3-cone test and the manual wheelchair maintenance knowledge test, we developed learning materials and videos for the wheelchair maintenance-training program. We also developed an online platform (www.iwheel.ca) to provide unlimited access for all wheelchair users in the community. Keeping track of participants' online activity can be added to the future randomized control trials. We believe this online platform access will have a significant influence on wheelchair users' knowledge improvement as there is limited access to manual wheelchair maintenance training materials (Taylor et al., 2015). The online platform has the potential to give researchers better understanding of participant demographics by reporting

the area and device (i.e., personal computer, cell phone or tablet) that participants connect from. However, ethics approval is needed to collect and report those data.

This study demonstrated the feasibility of conducting a larger clinical trial to evaluate the community based manual wheelchair maintenance program with use of the peer-led model. Having the capacity for creating a peer-led training for wheelchair users in the environment that extends beyond users' homes may increase participants community participation (Hosseini, Oyster, Kirby, Harrington, & Boninger, 2012; Kilkens, Post, Dallmeijer, van Asbeck, & van der Woude, 2005), and their quality of life (Hosseini et al., 2012). This feasibility study suggests there may be a potential benefit of peer-led manual wheelchair maintenance training, as this training had a positive effect in wheelchair users' self-efficacy and their satisfaction with participation, but this would need to be confirmed in future experimental research.

Our program is a structured training intervention that was developed through a systematic process and positively reviewed by researchers and technicians. There has been some effort to train clinicians regarding wheelchair maintenance, as I think it is still pretty limited (Toro et al., 2017; World Health Organization, 2013c). Our training program is a complementary educational tool to WHO's basic wheelchair service curriculum, which has been used to train clinicians (World Health Organization, 2013c). Additionally, this training can be used as an opportunity for an on-going wheelchair users' training program such as wheelchair skill training (Kirby et al., 2016).

To respond to the overarching question: “Can this feasibility work?” (Orsmond & Cohn, 2015), we evaluated feasibility outcomes including recruitment, data collection process, participant response, training satisfaction, management and scientific findings. We were able to meet the proposed goal for recruitment however in future work we may encounter many barriers that could adversely affect participation in research (e.g., frailty, mobility, fatigue, knowledge, physical environment) (Buffart, Westendorp, van den Berg-Emons, Stam, & Roebroeck, 2009; Rimmer, Riley, Wang, Rauworth, & Jurkowski, 2004) (Cardenas & Yilmaz, 2006). Reported retention rate for this feasibility study was high, and all the mentees completed the wheelchair maintenance study and all the mentors completed their peer-session. One of the main approaches to prevent the dropouts was recruiting a motivated participant who may have been more motivated to participate. We also recruited from a wheelchair user community, which may reinforce retention.

The wheelchair maintenance-training program had a very high completion rate for answering the surveys, questionnaires and assessment completion. The Masters candidate (ME), was in attendance of all activities and worked hard to keep things working. It was very personnel resource heavy from that aspect. Additionally, having a peer and mentor may have helped to achieve a high completion rate. It was promising that all of our participants completed the wheelchair maintenance-training program as intended.

Resource management (scheduling peer-led sessions) and coordinating a time which worked for both mentor and mentees took longer than expected and increased the length of the study. Fifteen one-on-one peer-sessions were conducted to teach mentees how to maintain their manual

wheelchair. The time required to complete a peer-session varied between participants (mentees). We had the highest cancellation rate (87%) for the peer-sessions. Scheduling and performing the peer-session was the least successful part of this feasibility study. Using more a systematic method such as automated or manual scheduling appointment programs (i.e., Gym or Salon management scheduling program) could decrease the cancellation rate and improve the peer-session scheduling rate (GymRush., 2018; Microsoft, 2018; SalonSoftware, 2018; wheniwork., 2018).

As hypothesized, wheelchair maintenance training program had positive impact on the knowledge about wheelchair maintenance, total wheelchair rolling resistance, and self-efficacy. Knowledge about wheelchair maintenance may help wheelchair users maintain their wheelchair and becoming physically active and influence frequency of participation in the community (Brodie M. Sakakibara, Miller, Routhier, Backman, & Eng, 2014).

There is an association between physical activity and wheelchair use self-efficacy (Phang, Martin Ginis, Routhier, & Lemay, 2012). Low self-efficacy can have a negative impact on wheelchair users' daily activity and community participation (B. M. Sakakibara, Miller, & Rushton, 2015), which may have a negative influence on quality of life for wheelchair users. In this study, participant self-efficacy (confidence to perform or teach wheelchair maintenance) improved. However, findings from this feasibility study are preparatory and must be interpreted with caution. Further investigation is required to determine the contribution of each component of manual wheelchair maintenance training on self-efficacy. Long-term follow-up is needed to

truly understand how wheelchair maintenance programs can influence the self-confidence of manual wheelchair users.

5.2 Future direction

This thesis lays the groundwork for a variety of future studies for wheelchair maintenance training and presents results that suggest that this feasibility program has a potential for exploring further in a randomized control trial. Wheelchair maintenance related research is in its infancy, and as the community of wheelchair users expands, the need for research about wheelchair maintenance intervention has been identified. This study was the first of its kind to examine peer-led wheelchair maintenance training, which was a participant-centered peer-led training model. It is beneficial to determine when is the best time to deliver the training program, determining which maintenance skills to focus on, and how long they should be taught (Potter, Wolfe, Burkell, & Hayes, 2004). The goal is, in the future studies can bring the wheelchair maintenance training to the community.

Translating the learning material to different languages will increase the opportunity to perform a multi-center research in the future. Adding a focus group conversation with participants would help better understand and address their wheelchair maintenance needs. In addition, performing structured interviews at the beginning and end of the study would help to improve the quality of the study (Spillane et al., 2010).

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Appendices

Appendix A Manual wheelchair knowledge test (35-question, by Ian Denison)

Please read each question carefully and select the best answer.

If you do not sure of the answer, select '**Don't know'**.

Easy:

Question01	**Which statement is true?**
Answer 1	Wheelchairs are maintenance free
Answer 2	Wheelchairs should never be used on uneven terrain
Answer 3	**Wheelchairs make life easier and harder**
Answer 4	Wheelchairs are all made in North America
Answer 5	Don't know

Question02	**How do you determine if a tire is pneumatic?**
Answer 1	Stick a sharp object into it
Answer 2	**Look for a valve on the inside of the rim**
Answer 3	Press on the tire and see if it squishes
Answer 4	Ask the wheelchair users
Answer 5	Don't know

Question03	**How can you tell if a wheelchair is a folding chair?**
Answer 1	It has folding instructions under the seat
Answer 2	**There is a large part of the frame in the shape of an "X" under the seat**
Answer 3	The chair is harder to push when it rains
Answer 4	The overall width of the chair is 8" wider than the seat
Answer 5	Don't know

Question04	**What is a push handle?**
Answer 1	A knob attached to the push rim so the user doesn't have to let go after each push
Answer 2	An adaptation to make it easier for a wheeler to open spring loaded doors
Answer 3	**An option on a chair that allows for an attendant to push the chair**
Answer 4	A setting on a power chair to use only in an emergency to go faster
Answer 5	Don't know

Question05	**Which statement is correct?**
Answer 1	A wheeler should only push using the push rims, never the tire
Answer 2	Semi pneumatic tire provide the same performance with half the air
Answer 3	The orientation of a wheelchair cushion doesn't matter
Answer 4	**Sling upholstery should be checked for tightness**
Answer 5	Don't know

Question 06	**What type of wheelchair is more efficient to move?**
Answer 1	Folding manual wheelchair
Answer 2	**Rigid manual wheelchair**
Answer 3	Folding adjustable manual wheelchair
Answer 4	Rigid adjustable manual wheelchair
Answer 5	Don't know

Question 07	**How often should you check the tire pressure?**
Answer 1	**Every 2 to 4 weeks**
Answer 2	Every 3 months
Answer 3	Every 6 months
Answer 4	Annually
Answer 5	Don't know

Question08	**Which statement is true?**
Answer 1	Wheelchairs should not be used in the rain
Answer 2	Every person with a disability in BC is eligible for a new wheelchair every five years
Answer 3	There are about 16 different sizes of wheelchair
Answer 4	**Casters typically range in size from 3" to 8"**
Answer 5	Don't know

Question09	**The most commonly required bearing maintenance is?**
Answer 1	Lubrication
Answer 2	**Hair removal**
Answer 3	Tension adjustment
Answer 4	Tracking adjustment
Answer 5	Don't know

Medium:

Question10	**What is a caster fork stem?**
Answer 1	**An part that sits between the caster housing and the caster fork**
Answer 2	The part of a utensil you hold when eating a caster
Answer 3	Not found on a wheelchair, only baby strollers
Answer 4	A device that sits inside the caster wheel to control spacing between the bearings
Answer 5	Don't know

Question11	**If you only have metric wrenches what size can you use on a ½" nut?**
Answer 1	11mm
Answer 2	12mm
Answer 3	**13mm**
Answer 4	14mm
Answer 5	Don't know

Question12	**When is it best to use an adjustable wrench?**
Answer 1	When the head of the nut has rounded off
Answer 2	**When you don't have the correct size wrench or socket**
Answer 3	When a fastener is secured with a locking washer
Answer 4	When working close to a painted surface to protect the finish
Answer 5	Don't know

Question13	**What common kitchen item is used to help remove back upholstery from wheelchairs?**
Answer 1	**Saran Wrap**
Answer 2	Pam cooking spray
Answer 3	Potato peeler
Answer 4	Washing up liquid
Answer 5	Don't know

Question14	**What type of fastener most commonly fastens seat upholstery to the seat rails?**
Answer 1	Set screw

Answer 2	**Machine screw**
Answer 3	Wood screw
Answer 4	Cork screw
Answer 5	Don't know

Question15	**The device used to stop a wheelchair from rolling is called a?**
Answer 1	Brake
Answer 2	Anti rotation device
Answer 3	**Wheel lock**
Answer 4	Caster lock
Answer 5	Don't know

Question16	**The main reason why the braking mechanism on a wheelchair malfunctions is?**
Answer 1	**Flat tire**
Answer 2	Poor adjustment
Answer 3	Device wear and tear
Answer 4	Wheeler too weak
Answer 5	Don't know

Question17	**Which of the following is <u>not</u> a lubricant for use on a wheelchair?**
Answer 1	Teflon
Answer 2	Graphite
Answer 3	**Lacquer thinner**
Answer 4	Pam cooking spray
Answer 5	Don't know

Question18	**The tire that is easiest to push on hard level surfaces is?**
Answer 1	Solid urethane tire
Answer 2	Semi pneumatic tire
Answer 3	**High pressure pneumatic tire(100+psi)**
Answer 4	Standard pneumatic tire (65psi)
Answer 5	Don't know

Question19	**The tire that is easiest to push on soft surfaces is:**
Answer 1	Solid urethane tire
Answer 2	**Low pressure pneumatic tire (20psi)**
Answer 3	High pressure pneumatic tire(100+psi)
Answer 4	Standard pneumatic tire (65psi)
Answer 5	Don't know

Hard:

Question20	**What shape is a torx fastener?**
Answer 1	Square
Answer 2	Hexagonal
Answer 3	Like a plus sign
Answer 4	**Six sided star**
Answer 5	Don't know

Question21	**How often shall you re-use a nylock nut?**
Answer 1	Once
Answer 2	Indefinitely
Answer 3	**Never**
Answer 4	Until it stops working

Answer 5	Don’t know

Question22	**What is the strongest method of joining two pieces of metal together?**
Answer 1	Pop rivets
Answer 2	Locking nut and bolt
Answer 3	Brazing
Answer 4	**Welding**
Answer 5	Don’t know

Question23	**What identification mark will you find on the head of a grade 5 bolt?**
Answer 1	It has a number 5 on it
Answer 2	**Three lines radiating from the centre**
Answer 3	Five lines radiating from the centre
Answer 4	A “V” engraved in the head
Answer 5	Don’t know

Question24	**What type of bearings are used in a wheelchair**
Answer 1	Cup and cone bearings
Answer 2	**Straight sealed bearings**
Answer 3	Needle roller bearings
Answer 4	Bronze bushings
Answer 5	Don’t know

Question25	**Wheel bearings should be adjusted so that:-?**
Answer 1	**The wheel reverses direction after stopping and there is minimal side to side play**
Answer 2	There is no play side to side in the wheel
Answer 3	The wheel spins freely and there is no evidence of grating
Answer 4	The wheeler is able to roll at least 12 feet on a hard surface with one push
Answer 5	Don’t know

Question26	**The linkage on the braking mechanism is best lubricated with?**
Answer 1	Pam cooking spray
Answer 2	WD40
Answer 3	**Teflon spray**
Answer 4	Grease
Answer 5	Don’t know

Question27	**Which of these does <u>not</u> prevent the wheel from turning?**
Answer 1	High mount push to lock
Answer 2	**Caster lock**
Answer 3	Low mount scissor lock
Answer 4	Spring loaded retractable lock
Answer 5	Don’t know

Question28	**The name given to a situation where the wheels are not parallel to each other when viewed from above is?**
Answer 1	Camber deviation
Answer 2	**Toeing error**
Answer 3	Directional asymmetry
Answer 4	Axle asymmetry
Answer 5	Don’t know

Question29	**If the wheels are 2 degrees away from being parallel, rolling resistance increases by:**
Answer 1	10%
Answer 2	20%

Answer 3	50%
Answer 4	**150%**
Answer 5	Don’t know

Question30	**When measuring to see if the wheels are parallel, check the width of the wheels at:**
Answer 1	**Axle height**
Answer 2	Top of the wheel
Answer 3	Bottom of the wheel
Answer 4	12” from the floor
Answer 5	Don’t know

Question31	**Caster stems should always be:**
Answer 1	**Vertical**
Answer 2	Horizontal
Answer 3	Directly over the caster
Answer 4	Level with the rear axle
Answer 5	Don’t know

Question32	**A “Snake bite” puncture typically occurs when:**
Answer 1	**The tire is under-inflated and hits a curb**
Answer 2	The spoke nipple is not protected by tape
Answer 3	A staple works it’s way through the carcass
Answer 4	The tire is over-inflated and subjected to heat
Answer 5	Don’t know

Question33	**Which statement is true?**
Answer 1	If a bearing seizes completely the wheel will not turn
Answer 2	Wheel bearings should be coated in grease or oil annually
Answer 3	**WD40 is a good cleaner**
Answer 4	Water should not be used to clean a wheelchair
Answer 5	Don’t know

Question34	**If you want to lubricate a bearing, you have to:**
Answer 1	Spray WD 40 where the axle and bearing touch
Answer 2	**Remove the seal, clean and lube**
Answer 3	Remove the balls and pack in grease
Answer 4	Bearings cannot be lubricated**.**
Answer 5	Don’t know

Question35	**Pneumatic tires will lose half of the initial air pressure in approximately:**
Answer 1	One week
Answer 2	One year
Answer 3	Six months
Answer 4	**Two months**
Answer 5	Don’t know

Appendix B Mentor Workshop Evaluation form

We trained mentors in a full day workshop, and then asked each to evaluate the workshop. The workshop evaluation form contains two main sections. In the first section, mentors evaluate the workshop in term of timing, location, and environment. In the second section, they evaluate the content of the workshop and knowledge of the facilitator presenting the material and answering questions.

Participant (Mentor) ID: _____ Date: _____

Workshop Setup
Did you bring a helper to the workshop? Yes ☐ No ☐
Did the I-WHEEL workshop begin on time? Yes ☐ No ☐
Were you informed about the objectives of the I-WHEEL workshop? Yes ☐ No ☐
Was enough time and space allocated for the I-WHEEL workshop? Yes ☐ No ☐

Skills Transfer			
Did you receive instruction on the following skills in the I-WHEEL workshop? *(Check Yes or No)*	Was the time spent: 1. Not enough? 2. Enough? 3. Too much? *(Circle a number)*	Assess facilitator's instruction of this skill. *(Draw a vertical line between 0 to 100)*	Did you learn how to perform this skill? *(Check Yes or No*
When and how to use each tool. Yes ☐ No ☐	1 2 3	0 _____100	Yes ☐ No ☐
How to fasten and loosen nuts and bolts. Yes ☐ No ☐	1 2 3	0 _____100	Yes ☐ No ☐
How to change a bearing. Yes ☐ No ☐	1 2 3	0 _____100	Yes ☐ No ☐
How to fix a wheel lock. Yes ☐ No ☐	1 2 3	0 _____100	Yes ☐ No ☐
How to maintain a toeing-error. Yes ☐ No ☐	1 2 3	0 _____100	Yes ☐ No ☐
How to adjust a caster stem. Yes ☐ No ☐	1 2 3	0 _____100	Yes ☐ No ☐

How to clean the wheelchair. Yes ☐ No ☐	1 2 3	0 _____100	Yes ☐ No ☐
How to lubricate the wheelchair. Yes ☐ No ☐	1 2 3	0 _____100	Yes ☐ No ☐
How to check and change a tire. Yes ☐ No ☐	1 2 3	0 _____100	Yes ☐ No ☐
Purpose and goals of peer-mentorship. Yes ☐ No ☐	1 2 3	0 _____100	Yes ☐ No ☐

Self-Assessment *(Draw a vertical line between 0 to 100)*	
My level of confidence in maintaining my wheelchair before the I-Wheel workshop was:	0 _____100
My level of confidence in maintaining my wheelchair after the I-Wheel workshop was:	0 _____100
My level of confidence in mentoring other wheelchair users before the I-Wheel workshop was:	0 _____100
My level of confidence in mentoring other wheelchair users after the I-Wheel workshop was:	0 _____100

Comments

Appendix C Workshop Facilitator Evaluation Form

Mr. Denison worked with and demonstrated each task to the mentors. As the facilitator, he helped mentors to understand each task in detail and answered all questions. He observed and evaluated each mentor's performance during the workshop. Mr. Denison provided feedback about mentors and their performance during the workshop.

Participant (Mentor) ID: _____ Date: _____

Session Details
Did the participant bring a helper to the peer mentorship session: Yes ☐ No ☐

Skills Transfer		
Indicate the skills covered in the I-WHEEL workshop. *(Check Yes or No)*	Was the time spent: 1. Not enough? 2. Enough? 3. Too much? *(Circle a number)*	Assess the improvement in the participant's skill level after the I-WHEEL workshop. *(Draw a vertical line between 0 to 100)*
When and how to use each tool. Yes ☐ No ☐	1 2 3	0 _____100
How to fasten and loosen nuts and bolts. Yes ☐ No ☐	1 2 3	0 _____100
How to change a bearing. Yes ☐ No ☐	1 2 3	0 _____100
How to fix a wheel lock. Yes ☐ No ☐	1 2 3	0 _____100
How to maintain a toeing-error. Yes ☐ No ☐	1 2 3	0 _____100
How to adjust a caster stem. Yes ☐ No ☐	1 2 3	0 _____100
How to clean the wheelchair. Yes ☐ No ☐	1 2 3	0 _____100
How to lubricate the wheelchair. Yes ☐ No ☐	1 2 3	0 _____100
How to check and change a tire. Yes ☐ No ☐	1 2 3	0 _____100
Purpose and goals of peer-mentorship. Yes ☐ No ☐	1 2 3	0 _____100

What percentage of the wheelchair maintenance material was covered in the I-WHEEL workshop?	0 _____100

Assessment *(Draw a vertical line between 0 to 100)*	
The participant's level of confidence in maintaining wheelchairs after the I-Wheel session was	0 _____100

Comments

_____

_____

_____

_____

_____

_____

_____

Appendix D Self-confidence Questionnaire

Instructions: A number of situations are described below that can challenge confidence. Using the sliding bar, please rate how confident you are as of now for each of the situation below.

Maintaining your wheelchair's bearings?	0 _____100
Maintaining your wheelchair's wheel locks?	0 _____100
Adjust your wheelchair's toeing?	0 _____100
Maintaining your wheelchair's caster stem?	0 _____100
As of now, can you clean your wheelchair?	0 _____100
Lubricating your wheelchair?	0 _____100
Maintaining your wheelchair's tires?	0 _____100
Teaching others how to maintain a wheelchair's bearings?	0 _____100
Teaching others how to maintain a wheelchair's wheel locks?	0 _____100
Teaching others how to maintain a wheelchair's toeing?	0 _____100
Teaching others how to maintain a wheelchair's caster stem?	0 _____100
Teaching others how to clean a wheelchair?	0 _____100
Teaching others how to lubricate a wheelchair?	0 _____100
Teaching others how to maintain their wheelchair tires?	0 _____100

Appendix E Mentee Knowledge and Maintenance Tracking form

We developed the Knowledge and Maintenance Tracking form to trace the acquisition of knowledge and maintenance activity (manual wheelchair related) of the participant during each visit. This form has two sections. In the first section, each participant answers questions about their online activities such as checking our website, watching online learning videos or reading the online maintenance manual. In the second section, the participant answers questions regarding their wheelchair maintenance activities. The last part of the form asks participants to rate his or her confidence in performing wheelchair maintenance by choosing a number between 0 (no-confidence) and 100 (confident).

Mentor ☐ Mentee☐ Participant ID: _____ Date: _____ Type of session:_____

Over the: Past week ☐ Past two weeks☐ Past three weeks ☐ Last month ☐

How many times did you visit *iwheel.ca*? (Circle your answer)	0 1 2 3 4 5 6 7 8 9 more
How did you access to the *iwheel.ca?* (check all that apply)	Smart phone ☐ Tablet ☐ Computer ☐
How many hours did you spent on the *iwheel.ca*? (Circle the time)	0hr 1-2hr 3-4hr 5hr more
What percentage of the reading did you cover?	Please draw a vertical line between 0 to 100 0_____100
What percentage of the video did you cover?	Please draw a vertical line between 0 to 100 0_____100
Did you use any other online resources?	Yes ☐ No ☐ ***If yes***: What website did you visit?

(Check the box if your answer is YES)	I checked my wheelchair's nuts & bolts	I changed the bearings in my wheelchair	I maintained my wheelchair's wheel locks	I maintained a toeing error in my wheelchair	I adjusted the caster stems in my wheelchair	I cleaned my wheelchair	I lubricated my wheelchair	I checked or changed my wheelchair's tire
Did you practice any of these skills on your wheelchair?	☐	☐	☐	☐	☐	☐	☐	☐
Please check if you did the task alone	☐	☐	☐	☐	☐	☐	☐	☐

Comment:

How much time did you spend on wheelchair maintenance? (Circle the time)	0hr 1-2hr 3-4hr 5h
How confident am I to maintain my wheelchair now?	Please draw a vertical line betwee 0_____

Appendix F Mentor Peer-mentorship Evaluation form

Each mentor worked with three mentees and had a 3 hour one-on-one peer training session with each mentee. The Mentor Peer-Memership Evaluation form asked the mentor to evaluate their mentee after completing their peer-session training. The mentor also evaluated the mentee in each task they performed during the peer-session. At the end of this form, the mentor was also asked to rate their confidence level in performing a peer-session.

Participant (mentor) ID: _____ Date: _____The peer-session took about _____ hours.

Did you bring a helper to the peer mentorship session: Yes ☐ No ☐

Did your mentee bring a helper to the peer mentorship session: Yes ☐ No ☐

Peer session Setup	Yes	No
a. Was it easy to set a time and location for the peer mentorship session?	☐	☐
b. Was there enough space and tools to run the peer mentorship session?	☐	☐

Topics	I was able to cover this topic in the peer mentorship session	Time spent for this skill was? 1. Not enough 2. Enough 3. Too much time Circle a number	How well do you think your mentee learned the topic? (After peer-session) Please draw a vertical line between 0 to 100
Knowledge about tools	YES ☐ NO ☐	1 2 3	0 _____ 100
Know how to fasten and loosen nuts & bolts	YES ☐ NO ☐	1 2 3	0 _____ 100
How to change a bearing	YES ☐ NO ☐	1 2 3	0 _____ 100
How to fix a wheel lock		1 2 3	0 _____ 100

	YES ☐ NO ☐		
How to maintain a toeing error	YES ☐ NO ☐	1 2 3	0 100
How to adjust caster stem	YES ☐ NO ☐	1 2 3	0 100
How to clean the wheelchair	YES ☐ NO ☐	1 2 3	0 100
How to lubricate a wheelchair	YES ☐ NO ☐	1 2 3	0 100
How to check & change the tires	YES ☐ NO ☐	1 2 3	0 100
Peer-mentorship	YES ☐ NO ☐	1 2 3	0 100

How confident was I to mentor my mentee before peer mentorship session	0 100
How confident I am to mentor my mentee after peer mentorship session	0 100

Comment:

Appendix G Mentee Peer-mentorship evaluation form

Each mentee has a 3 hour one-on-one peer training session with his or her mentor. At the end of their session, they were handed a Peer-mentorship evaluation form. This asked them to evaluate their mentor and their peer-session. At the end of this form the mentee was also asked to rate their confidence level in performing wheelchair maintenance.

Participant (mentor) ID: _____ Date: _____The peer-session took about _____ hours.

Did you bring a helper to the peer mentorship session: Yes ☐ No ☐

Did your mentee bring a helper to the peer mentorship session: Yes ☐ No ☐

Peer session Setup	**Yes**	**No**
a. Was it easy to set a time and location for the peer mentorship session?	☐	☐
b. Was there enough space and tools to run the peer mentorship session?	☐	☐

Topics	This topic covered in the peer mentorship session	Time spent for this skill was? 1. Not enough 2. Enough 3. Too much time Circle a number	Mentor was able to teach this skill	How well do you think you learned the topic? (After peer-session) Please draw a vertical line between 0 to 100
Knowledge about tools	YES ☐ NO ☐	1 2 3	YES ☐ NO ☐	Please draw a vertical line between 0 to 100 0_____100
Know how to fasten and loosen nuts & bolts	YES ☐ NO ☐	1 2 3	YES ☐ NO ☐	0_____100
How to change a bearing	YES ☐ NO ☐	1 2 3	YES ☐ NO ☐	0_____100
How to fix a wheel lock	YES ☐ NO ☐	1 2 3	YES ☐ NO ☐	0_____100

How to maintain a toeing error	YES ☐ NO ☐	1 2 3	YES ☐ NO ☐	0_____100
How to adjust caster stem	YES ☐ NO ☐	1 2 3	YES ☐ NO ☐	0_____100
How to clean the wheelchair	YES ☐ NO ☐	1 2 3	YES ☐ NO ☐	0_____100
How to lubricate a wheelchair	YES ☐ NO ☐	1 2 3	YES ☐ NO ☐	0_____100
How to check & change the tires	YES ☐ NO ☐	1 2 3	YES ☐ NO ☐	0_____100
Peer-mentorship	YES ☐ NO ☐	1 2 3	YES ☐ NO ☐	0_____100
How confident was I to maintain my wheelchair before peer mentorship session				0_____100
How confident am I to maintain my wheelchair after peer mentorship session				0_____100

Comments:

Appendix H Research Coordinator Peer-mentorship observation form

The research coordinator attended and observed all fifteen, one-on-one peer-sessions and completed a Peer-mentorship observation form for each session. This form focused on two sections. 1) time management of the peer-session and 2) peer-mentorship and tasks completed during the peer-session. The research coordinator also recorded any problems and suggested improvements that could potentially enhance the peer-sessions in the future.

Mentee ID: _____ Mentor ID:_____ Date: _____

Time Management			
Peer-session time allocation	**Topic covered**	**Time for selected topics**	**Topic takes more than 30 minutes**
Started on-time Did not start on-time Finished on time Session was more then 3-hr Session was less than 3-hr	Tools & suggested supplement Bearings Wheel lock Toeing error Caster stem Cleaning Lubrication tires	One peer-session was enough (<3 hours) One peer review session was needed, but more than three hours was required. Multiple peer-sessions needed	Tools & suggested supplement Bearings Wheel lock Toeing error Caster stem Cleaning Lubrication tires

Peer-mentoring				
Mentor participation	**Mentee participation**	**Mentee's helper participation**	**Training**	**Learning**
Mentor explained the goals Mentor was able to reach the goals Mentor was able to answer the	Mentee followed the mentor's instructions Mentee was able to explain the selected task, which was taught in the session.	Mentee brought helper to the peer-session Mentee's helper assisted the mentee. No helper	All the selected maintenance skills taught during the peer-session Mentor asked mentee to do the selected task by him/her-self	Mentee understood the reasons behind the selected task/topic

mentee's questions				

Problem during peer-session
Mentor did not review learning documents Mentor didn’t demonstrate/fix anything on manual wheelchair Mentee didn't ask question Mentee's helper was over involved Mentor did not cover all the selected topic

Improvement for peer-session
More tools and lubrication needed to demonstrate during peer-session We need different types of wheelchair and parts in the session. Use video in the session to illustrate task completion

General Note

Appendix I Mentee Exit survey

.

Participant ID: _____ Date: _____

What activities do you use your manual wheelchair for?	
How many manual wheelchairs do you have?	
How old is your newest manual wheelchair?	
How did you research which manual wheelchair was the best for you?	
Did your OT/PT provide recommendations on which manual wheelchair to get?	
Where did you get your newest manual wheelchair?	
What is the brand of your newest manual wheelchair?	
How much did you pay for your newest manual wheelchair?	
Do you have insurance (extended benefit) for wheelchair maintenance?	
Rating the components of the I-WHEEL Program | Rate your manual wheelchair maintenance peer-mentorship session	Very good Good Fair Satisfactory Poor
Rating the components of the I-WHEEL Program | Rate your mentor's knowledge of manual wheelchair maintenance	Very good Good Fair Satisfactory Poor
Rating the components of the I-WHEEL Program | Rate the length of time allocated to your peer-mentorship session.	Very good Good Fair Satisfactory Poor
Rating the components of the I-WHEEL Program | Rate your access to the wheelchair maintenance learning materials.	Very good Good Fair Satisfactory Poor
Rating the components of the I-WHEEL Program | Rate the tools you used in the session to maintain your wheelchair.	Very good Good Fair Satisfactory Poor
How confident were you before I-WHEEL program about how to maintain your wheelchair?	0_____100
How confident are you (after I-WHEEL program) about how to maintain your wheelchair?	0_____100

How would you describe your role as a mentee/mentor in the I-WHEEL program?	
Would you recommend the I-WHEEL program to other manual wheelchair users?	
Did you find the peer-mentorship relationship difficult to cope with? If so, why?	
How would you improve the peer-mentorship session (e.g. what features would you add)?	
What was your favorite maintenance topic? Why?	
What was your least favorite maintenance topic? Why?	
How would you improve the I-WHEEL program (e.g. what features would you add)?	

Appendix J I-Wheel checklist

Each mentee visited four times. We created the I-Wheel checklist form so the research coordinator could track the task/data collection required during each visit. No identifiable information (e.g., name, date of birth) was collected on in this form.

Participant ID:

☐ Consent form Signed (DATE:_____)
☐ First assessment (DATE:_____)

- Demographic form
- Knowledge test
- KMT Self report
- 3-cone test **Elbow:_____degree**
  T_1_ _ _ _ *s* *(Cone _ _ _)* T_2_ _ _ _ _s *(Cone _ _ _)* T_3_ _ _ _ _s *(Cone _ _ _)*
- Drag test
- 6MPT Number of Loop: # _____ft
- Record the tire pressure : Left_____PSI Right _____PSI
- Resource presented (Website ☐ Facebook ☐ Twitter ☐)

Peer-session scheduled Yes ☐ No ☐ Date:_____ **(doodle schedule)**

☐ Peer-mentorship session (DATE:_____ Hour:_____) Mentor ID:_____

- Session Observed Yes ☐ No ☐
- Peer-Session evaluation form by Mentee ☐
- Peer-Session evaluation form by Mentor ☐

Doodle sent Yes ☐ No ☐ Second assessment scheduled Date:_____

☐ Second assessment (DATE:_____)

- Demographic form
- Knowledge test
- KMT Self report
- 3-cone test **Elbow:_____degree**

T_1_ _ _ _ *s* *(Cone _ _ _)* T_2_ _ _ _ _s *(Cone _ _ _)* T_3_ _ _ _ _s *(Cone _ _ _)*

- Drag test
- 6MPT Number of Loop: # _____ft
- Record the tire pressure: Left_____PSI Right _____PSI
- Resource presented (Website ☐ Facebook ☐ Twitter ☐)

Third assessment scheduled Yes ☐ No ☐ Date:_____

☐ Third assessment (DATE:_____)

- Demographic form
- Knowledge test
- KMT Self report
- 3-cone test **Elbow:_____degree**
  T_1_ _ _ _ *s* *(Cone _ _ _)* T_2_ _ _ _ _s *(Cone _ _ _)* T_3_ _ _ _ _s *(Cone _ _ _)*
- Drag test
- 6MPT Number of Loop: # _____ft
- Record the tire pressure: Left_____PSI Right _____PSI
- Resource presented (Website ☐ Facebook ☐ Twitter ☐)

Appendix K Data collection and peer-session date

		Data collection and peer-session date			
	ID	Assessment01	Peer-session	Assessment02	Assessment03
1	Iwheel001	18-Aug	29-Aug	10-Sep	21-Sep
2	Iwheel002	18-Jun	23-Jun	22-Aug	12-Sep
3	Iwheel003	16-Jun	27-Jun	8-Jul	17-Aug
4	Iwheel004	30-May	30-Jun	17-Aug	31-Aug
5	Iwheel005	2-Jun	26-Sep	12-Oct	20-Oct
6	Iwheel006	2-Jun	19-Sep	11-Oct	18-Oct
7	Iwheel007	27-May	29-Jun	16-Sep	7-Oct
8	Iwheel008	9-Jun	24-Jun	14-Sep	26-Sep
10	Iwheel010	7-Sep	9-Sep	27-Oct	1-Nov
11	Iwheel012	10-Sep	23-Sep	7-Oct	21-Oct
12	Iwheel013	7-Sep	3-Oct	18-Oct	26-Oct
13	Iwheel014	19-Oct	24-Oct	26-Oct	31-Oct
14	Iwheel018	30-Aug	20-Sep	4-Oct	25-Oct
15	Iwheel019	15-Sep	29-Sep	7-Oct	27-Oct
16	Iwheel023	9-Sep	9-Sep	14-Sep	29-Sep

Appendix L Number of days between each visit

	Days in between		
ID	**1st to peer-session**	**Peer-session to 2nd assessment**	**2nd to 3rd assessment**
Iwheel001	10	11	10
Iwheel002	4	59	20
Iwheel003	10	10	39
Iwheel004	30	47	13
Iwheel005	115	15	7
Iwheel006	108	21	6
Iwheel007	32	78	20
Iwheel008	14	81	11
Iwheel010	1	47	4
Iwheel012	12	13	13
Iwheel013	25	14	7
Iwheel014	4	1	4
Iwheel018	20	13	20
Iwheel019	13	7	19
Iwheel023	0	4	14
Average days performed	28	31	16
Our proposed days	7	7	30

Appendix M Self-confidence summary table (mentor/ Baseline)

	Currently knowing the tools, nuts, bolts and screws required to maintain your wheelchair?	Maintaining your wheelchair's bearings?	Maintaining your wheelchair's wheel locks?	Adjust your wheelchair's toeing?	Maintaining your wheelchair's caster stem?	As of now, can you clean your wheelchair?	As of now, can you Lubricating your wheelchair?	As of now, can you Maintaining your wheelchair's tires?	As of now, can you teaching others about tools, nuts, bolts and screws?	As of now, can you teaching others how to maintain a wheelchair's bearings?	As of now, can you teaching others how to maintain a wheelchair's wheel locks?	As of now, can you teaching others how to maintain a wheelchair's toeing?	As of now, can you teaching others how to maintain a wheelchair's caster stem?	As of now, can you teaching others how to clean a wheelchair?	As of now, can you teaching others how to maintain a wheelchair's tires?	As of now, can you teaching others how to maintain their wheelchair tires?
Mentor 002	86	80	91	92	81	100	100	89	86	88	92	92	89	100	94	93
Mentor 003	75	82	89	83	67	95	95	96	80	90	95	88	68	96	96	96
Mentor 004	85	75	100	85	50	91	85	100	75	75	75	75	48	65	95	95
Mentor 005	100	100	90	90	90	100	100	100	100	100	90	100	90	100	100	100
Mentor 006	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Total (n=5)																

1= strongly disagree; 2=Disagree; 3= Neutral; 4= Agree; 5= strongly agree

Appendix N Self-confidence summary table (mentor/ post-test)

	required to maintain your wheelchair? Currently knowing the tools, nuts, bolts and screws	Maintaining your wheelchair's bearings?	Maintaining your wheelchair's wheel locks?	Adjust your wheelchair's toeing?	Maintaining your wheelchair's caster stem?	As of now, can you clean your wheelchair?	wheelchair? As of now, can you Lubricating your	wheelchair's tires? As of now, can you Maintaining your	nuts, bolts and screws? As of now, can you teaching others about tools,	maintain a wheelchair's bearings? As of now, can you teaching others how to	maintain a wheelchair's wheel locks? As of now, can you teaching others how to	maintain a wheelchair's toeing? As of now, can you teaching others how to	maintain a wheelchair's caster stem? As of now, can you teaching others how to	clean a wheelchair? As of now, can you teaching others how to	maintain a wheelchair's tires? As of now, can you teaching others how to	maintain their wheelchair tires? As of now, can you teaching others how to
Mentor 002	95	97	98	91	92	100	100	99	95	97	97	92	96	100	100	96
Mentor 003	86	89	92	88	85	94	95	93	90	92	91	88	87	92	91	93
Mentor 004	75	75	85	75	39	75	75	75	65	65	65	65	24	65	65	75
Mentor 005	100	100	95	95	100	100	100	95	100	100	95	100	100	100	100	100
Mentor 006	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Total (n=5)																

1= strongly disagree; 2=Disagree; 3= Neutral; 4= Agree; 5= strongly agree

Appendix O Self-confidence summary table (mentee/ Baseline)

	Currently knowing the tools, nuts, bolts and screws required to maintain your wheelchair?	Maintaining your wheelchair's bearings?	Maintaining your wheelchair's wheel locks?	Adjust your wheelchair's toeing?	Maintaining your wheelchair's caster stem?	As of now, can you clean your wheelchair?	As of now, can you Lubricating your wheelchair?	As of now, can you Maintaining your wheelchair's tires?	As of now, can you teaching others about tools, nuts, bolts and screws?	As of now, can you teaching others how to maintain a wheelchair's bearings?	As of now, can you teaching others how to maintain a wheelchair's wheel locks?	As of now, can you teaching others how to maintain a wheelchair's toeing?	As of now, can you teaching others how to maintain a wheelchair's caster stem?	As of now, can you teaching others how to clean a wheelchair?	As of now, can you teaching others how to maintain a wheelchair's tires?	As of now, can you teaching others how to maintain their wheelchair tires?
I-WHEEL001	90	97	88	32	97	100	76	98	77	76	93	26	87	96	100	96
I-WHEEL002	0	0	82	0	0	80	0	61	0	1	61	0	0	81	59	59
I-WHEEL003	100	100	100	100	100	100	100	100	73	78	72	51	69	100	93	92
I-WHEEL004	0	0	49	0	0	51	0	49	0	0	0	0	0	0	0	0
I-WHEEL005	91	36	199	3	52	100	78	100	85	31	100	3	1	100	77	77
I-WHEEL006	71	58	64	44	51	80	72	72	60	50	50	38	49	62	61	59
I-WHEEL007	0	0	0	0	0	50	0	50	0	0	0	0	0	0	0	0
I-WHEEL008	100	100	100	80	15	100	100	100	100	90	80	80	25	90	100	100
I-WHEEL010	30	6	10	0	8	58	57	58	0	0	0	0	0	0	56	55
I-WHEEL012	30	40	40	0	70	80	60	50	10	20	20	0	30	70	70	70
I-WHEEL013	0	0	0	0	0	21	0	0	0	0	0	0	0	64	83	81
I-WHEEL014	90	30	60	20	95	100	90	100	90	70	70	0	80	90	90	100
I-WHEEL018	100	88	85	58	86	100	35	100	100	90	77	35	63	100	100	100
I-WHEEL019	0	0	0	0	0	85	10	82	0	0	0	0	0	86	86	86
I-WHEEL023	43	7	9	9	10	25	25	45	21	0	0	0	0	0	9	8
Total (n=15)																

1= strongly disagree; 2=Disagree; 3= Neutral; 4= Agree; 5= strongly agree

Appendix P Self-confidence summary table (mentee/ post-test)

	Currently knowing the tools, nuts, bolts and screws required to maintain your wheelchair?	Maintaining your wheelchair's bearings?	Maintaining your wheelchair's wheel locks?	Adjust your wheelchair's toeing?	Maintaining your wheelchair's caster stem?	As of now, can you clean your wheelchair?	As of now, can you Lubricating your wheelchair?	As of now, can you Maintaining your wheelchair's tires?	As of now, can you teaching others about tools, nuts, bolts and screws?	As of now, can you teaching others how to maintain a wheelchair's bearings?	As of now, can you teaching others how to maintain a wheelchair's wheel locks?	As of now, can you teaching others how to maintain a wheelchair's toeing?	As of now, can you teaching others how to maintain a wheelchair's caster stem?	As of now, can you teaching others how to clean a wheelchair?	As of now, can you teaching others how to maintain a wheelchair's tires?	As of now, can you teaching others how to maintain their wheelchair tires?
I-WHEEL001	90	100	100	70	90	100	90	100	80	100	92	82	94	95	94	100
I-WHEEL002	40	26	100	60	60	100	71	80	40	40	100	50	61	100	80	100
I-WHEEL003	100	100	100	100	100	100	100	100	91	97	100	100	93	100	100	100
I-WHEEL004	85	75	89	30	70	100	60	70	50	50	60	20	50	100	50	50
I-WHEEL005	99	99	100	97	99	100	99	100	94	95	100	74	79	100	100	99
I-WHEEL006	86	84	83	84	85	99	88	89	57	60	62	73	71	83	69	74
I-WHEEL007	75	50	80	50	50	70	60	80	60	50	60	50	50	60	50	60
I-WHEEL008	100	100	100	100	90	100	100	100	100	100	100	100	90	100	100	100
I-WHEEL010	33	39	27	0	0	75	78	66	0	35	28	0	0	68	73	68
I-WHEEL012	80	100	100	100	100	100	100	100	50	60	60	70	80	100	100	100
I-WHEEL013	22	87	81	68	79	75	74	96	4	89	88	65	75	92	76	99
I-WHEEL014	90	80	100	80	100	100	100	100	90	95	100	80	100	100	100	100
I-WHEEL018	86	100	100	100	100	100	98	100	100	100	100	100	96	100	100	100
I-WHEEL019	75	100	77	51	82	100	100	100	51	52	49	50	50	100	50	100
I-WHEEL023	93	97	99	78	79	100	100	100	80	80	79	65	80	93	97	95
Total (n=15)																

1= strongly disagree; 2=Disagree; 3= Neutral; 4= Agree; 5= strongly agree

Appendix Q Exit survey summary table (mentee)

(e.g. what features would you add)?? How would you improve the I-WHEEL program	wheelchair technology Learn about new manual	
Why? What was your least favorite maintenance topic?	Nuts, bolts, screws	
What was your favorite maintenance topic? Why?	Learning about right lubricants	
session (e.g. what features would you add)? How would you improve the peer-mentorship	Nothing to improve	
difficult to cope with? If so, why? Did you find the peer-mentorship relationship	No	
other manual wheelchair users? Would you recommend the I-WHEEL program to	Very beneficial	
mentee/mentor in the IWHEEL program? How would you describe your role as a	Learned few things	
about how to maintain your wheelchair?? How confident are you (after I-WHEEL program)	90	
about how to maintain your wheelchair? How confident were you before I-WHEEL program	82	
you used in the session to maintain your Rate the tools Rating the components of the I-WHEEL Program |	5	
access to the wheelchair maintenance learning Rate your Rating the components of the I-WHEEL Program |	5	
peer-mentorship session. Rate the length of time allocated to your Rating the components of the I-WHEEL Program |	5	
wheelchair maintenance. Rate your mentor's knowledge of manual Rating the components of the I-WHEEL Program |	5	
peer-mentorship session Rate your manual wheelchair maintenance Rating the components of the I-WHEEL Program |	5	
maintenance? wheelchair Do you have insurance (extended benefit) for	Yes	
wheelchair? How much did you pay for your newest manual	$8500	
wheelchair? What is the brand of your newest manual	Ti-lite	
Where did you get your newest manual wheelchair?	Advance mobility	
which manual wheelchair to get? Did your OT/PT provide recommendations on	No	
the best for you? How did you research which manual wheelchair was	Internet, friends	
How old is your newest manual wheelchair?	4m	
How many manual wheelchairs do you have?	4	
wheelchair for? What activities do you use your manual	Everyday use, dancing, tennis	
I-WHEEL001		

I-WHEEL 002	everyday wheeling Table Tennis, Parc Gym, sometimes Floorball,	1	3 1/2 years	Through OT and PT at GF-Strong	Yes	Advanced Mobility	Tilite Aero Z	$4635	Yes	5	4	4	5	5	2	60	a mentor the guidance of My role was to learn how to maintain my chair from	Yes	No	remember somethings after one session I would add more than one session as it was hard to	common problem Caster ailining becsuse caster flutter is my most	No least favorite	Add more session times
I-WHEEL 003	ambulatory. Everything. I am no longer	2	6-month	OT, Sales Rep, Internet, Trade Show	yes	SelfCare Motion Composites through	Motion Composites Helio C2	$6000	Yes	4	5	4	4	4	100	100	Ginny pig	Yes	No	more confidence of the mentors It will get better over time with	N/A	N/A	confidence mentor practice to develop

a follow up between mentor and mentee	the web–site to refresh my memory/understanding will help	Tracking and pulling one way. It was over my head – but having	about wheelchair maintenance than I thought I did	tools and nuts, bolts & screws – make me realize I think more	Divide it into 2 sessions with a couple of weeks in between	very well	Nope – thought Kris was able to deal with bith Bing and I very	Yes and I have several times	I was willing but not sure what to expect	80	10	4	5	3	5	4	on my own when it comes to maintenance
not sure – I don't think so. They paid for the chair but I think I'm	$2900	TiLite Aero X Foldable Ultralight	on–line from 1–800–wheelchairs.ca	not really she just re-measured me for size and angles	through suppliers	talked to people that use a chair, on–line, tested wheelchairs	less than 1 year	2	accessible for my scooter, travel	isn't	Desk work, dancing, visiting friends & family when their home	I-WHEEL 004	the program to GF as a Thursday meeting	I would add walkers , power chairs and I would mention	there were none	Camber / caster adjustment. I .had no clue i was way off	better set up rooms with space all ariund table
Not at all	Yes	required	99	25	4	5	5	4	5	No	$10,780,	Levo	Advanced Mobility	Yes	PT	3 YEARS OLD	3
Everything	I-WHEEL 005																

I-WHEEL 006	Everyday movement in house, driving and then using for most activities out of the house, shopping etcetera	1	2.5 years	Physio and wheelchair supplier specified	Yes	Motion Specialties	Ti–lite	Ministry funds	Don't know, no, unless ministry provides	5	5	5	4	5	50	76	Thankful	Yes	No	Follow up session, because things that seem obvious when learning in the first session, are not when putting into practice. Questions can	Wheel alignment issues. Most important.	none	Just what \i said above. A follow up mentor session to confirm abilities and questions.
I-WHEEL 007	For going longer distance, and travelling.	3	Four year old	Talked to OT & wheelchair users.	Yes	Internet	Tilite	$ 2,000	No	5	5	5	4	5	50	70	As a learner, and participant.	Yes	Mot at all	The session was a bit long, otherwise was perfect!	The hands on aspect. I can see the actua results.	They were all interesting and challenging.	The program was well done and I surely appreciate it.

I-WHEEL008	everything	2	1 month	own experience, online info, advice from friends	no, but provided recommendations on sizing	online, Sportaid	TiLite ZR Superlight	US $6700	Yes	4	4	5	5	5	90	95	as a mentee, to learn as much as I could while contributing what I know	Yes if they are not mechanically inclined	No, my mentor and I got along great!	maybe first go over what mentee knows and then concentrate on the rest	adjusting toe-in, because I learned most there
I-WHEEL010	exercise, half marathons, sometimes day to day depending on ability level	2	4 Years	Listened to OT	yes	Tilight	Tilight	11000	Yes	3	4	4	5	3	58	63	Fine, it was nice being told by someone who is a wheelchair user but also it was not the most informed wheelchair users so in some ways, I would have prefered be tough by an OT or researcher who took it all more seriously	Yes if they did not know much and had lots to learn	Nope, generally easy	More systematic plan for making sure that each person gets similar information and find a way to make sure that people actually use the online resources. Maybe actually walk them through it or something	Learning about bearings

I-WHEEL008	maybe collect maintenance info on various types of wheelchairs	Cleaning, 'cause I'm a guy :)))	adjusting toe-in, because I learned most there rest	then concentrate on the	maybe first go over what mentee knows and	No, my mentor and I got along great!	Yes if they are not mechanically inclined know	contributing what I	as a mentee, to learn as much as I could while	95	90	5	5	5	4	4	Yes	2	1 month	own experience, online info, advice from friends	no, but provided recommendations on sizing
I-WHEEL010	how to make your wheels not wabble	just things that did not apply to my wheelchair	Learning about bearings	that people actually use the online resources. Maybe actually walk them through it or something	More systematic plan for making sure that each person gets similar information and find a way to make sure	Nope, generally easy	Yes if they did not know much and had lots to learn	more seriously	Fine, it was nice being told by someone who is a wheelchair user but also it was not the most informed wheelchair users so in some ways, I would have prefered be tough by an OT or researcher who took it all	63	58	3	5	4	4	3	Yes	2	4 Years	Listened to OT	yes

mentor sessions with the give the mentee more time to absorb the information and hold more	GOING OVER THE PARTS ON THE CHAIR 2 PART SERIES, ONE FOR CLEANING, ONE FOR
there wasn't	ETC., COULD NOT TAKE THAT INFO IN LEARNING ABOUT DIFFERENT NUTS BOLTS
wheel cleaning	EASIER THAN I THOUGHT CLEANING, MY CHAIR REALLY NEEDED IT, WAS
taking the wheels components appart hold more sessions to learn the details of taking the casters and	LESS READING THE BOOK, MORE HANDS ON
ago No because I knew the person from many years	No
Yes	Yes
iwheel manual is a big help There maybe some help required but overall I am confident that	LEARNING AND LISTENING
100	78
20	16
5	5
5	5
5	4
5	4
5	4
Yes	No
1000	7,000
Ti Lite	PGK
Motion Specialities	ADVANCED
Yes	Yes
with the help of OT and vendor	ONLINE, OT/PT, DEALER
over 10 years old	7 Years
2	1
travel Daily every day to get around. play sports and	EVERY DAY USE, GYM
I-WHEEL012	I-WHEEL013

ATTEMPT TO FIND A SOLUTION AND DO IT SET UP A REAL LIFE SITUATION AND THEN		AREAS TO PERFORM DAILY MAINTENANCE try ND FIND A LOCATON WITH TOOOLS AND
EVIDENT FOR ME HOW TO CLEAN A WHEELCHAIR IS FAIRLY SELF		filling out end of program evaluation
PRIOR TOEING ISSUES BECAUSE I KNEW NOTHING		bearings one of most important parts on chair
EXTENDED ONE ON ONE TIME		unknown
No		No
Yes		Yes
AQUIRED GOOD LEARNING EXPERIENCE HANDS ON SKILLS		learning
95		93
75		56
5		5
5		5
3		4
4		5
4		4
No		BC medical
nothing		no idea
Invacare A4		Invacare
GF-Strong		McDonalds health
Recommended types not brands		Yes
OT plus internet research		with therapist
More than 8 years		years
1		1
general transport		daily living
I-WHEEL 014	I-WHEEL 018	I-WHEEL 019

I-WHEEL 023	Every day stuff	2	3 years	Help from physiotherapist	Yes	Advanced mobility	Quickie	$7900	No	5	5	5	4	5	63	91	Mentee	I Would	No	It's good as is.	scared me before. Maintaining casters. Because it always	Enjoy get them all.	It's good as it is.
Total (n= 15)																							

5= Very good' 4= Good; 3= Fair; 2= Satisfactory; 1= Poor

Appendix R Knowledge test result

ID	1st (Baseline) data collection				2nd data collection				Third data collection			
	easy	medium	hard	Total	easy	medium	hard	Total	easy	medium	hard	Total
iwheel001	8	5	2	15	9	6	9	24	9	8	8	25
iwheel002	7	3	3	13	7	7	6	20	7	6	5	18
iwheel003	8	5	7	20	8	7	8	23	8	7	6	21
iwheel004	4	1	1	6	6	7	9	22	6	6	10	22
iwheel005	6	5	5	16	8	5	10	23	8	5	8	21
iwheel006	4	5	6	15	5	4	9	18	4	7	6	17
iwheel007	6	2	4	12	6	7	12	25	6	8	11	25
iwheel008	9	7	11	27	9	8	13	30	9	8	12	29
iwheel010	5	3	4	12	6	4	5	15	7	4	6	17
iwheel012	7	2	4	13	7	3	10	20	7	4	9	20
iwheel013	6	2	4	12	9	7	7	23	9	7	7	23
iwheel014	5	6	2	13	6	7	8	21	7	7	11	25
iwheel018	8	6	7	21	8	8	11	27	8	8	10	26
iwheel019	7	4	4	15	8	4	7	19	8	5	3	16
iwheel023	6	3	1	10	7	8	5	20	7	7	8	22

Appendix S The 3-cone test result table

	Visit one	Visit two	Visit three
iwheel001	**15.84**	**14.53**	**14.08**
iwheel002	**16.65**	**17.11**	**17.36**
iwheel003	**20.71**	**18.54**	**20.48**
iwheel004	**35.8**	**31.79**	**33.59**
iwheel005	**18.93**	**18.22**	**17.47**
iwheel006	**29.47**	**25.71**	**25.13**
iwheel007	**32.42**	**28.32**	**27.78**
iwheel008	**15.14**	**14.87**	**14.54**
iwheel010	**18.66**	**17.6**	**18.49**
iwheel012	**18.16**	**17.26**	**18.07**
iwheel013	**27.88**	**22.76**	**22.82**
iwheel014	**16.71**	**18.39**	**17.76**
iwheel018	**24.83**	**27.44**	**26.54**
iwheel019	**17.31**	**16.93**	**17.44**
iwheel023	**18.45**	**18.76**	**17.22**

Sensitivity analysis showed the effect size for the 3-cone test was $f = 0.44$.

Appendix T The 6-minute push result table

	Visit one	Visit two	Visit three
iwheel001	**863.59**	**984.23**	**956.89**
iwheel002	**700.77**	**727.01**	**680.41**
iwheel003	**602.68**	**661.14**	**658.58**
iwheel004	**329.49**	**342.23**	**341.04**
iwheel005	**636.94**	**668.64**	**748.47**
iwheel006	**368.38**	**437.11**	**448.39**
iwheel007	**530.87**	**464.88**	**525.57**
iwheel008	**697.32**	**843.41**	**861.58**
iwheel010	**835.91**	**858.68**	**808.66**
iwheel012	**625.54**	**602.35**	**629.26**
iwheel013	**594.42**	**598.08**	**619.84**
iwheel014	**774.8**	**740.63**	**783.64**
iwheel018	**530.2**	**537.88**	**531.14**
iwheel019	**723.75**	**749.47**	**732.4**
iwheel023	**691.9**	**697.32**	**702.69**

Appendix U The drag fore result table (Two participant traveled in after their second assessment)

	Rolling Resistance			
	ID	Assessment01	Assessment02	Assessment03
1	Iwheel001	9.40714325	7.130596775	8.773679692
2	Iwheel002	16.04128291	12.35853931	12.81566822
3	Iwheel003	12.74579736	9.767285037	12.57260869
4	Iwheel004	14.57548853	12.5347828	13.07605178
5	Iwheel005	12.98945673	10.38494668	10.75736605
6	Iwheel006	18.48309626	19.54986099	20.19152571
7	Iwheel007	9.001430133	6.27281829	9.157382866
8	Iwheel008	10.35209857	9.628591309	11.81901485
9	Iwheel010	15.04571375	15.29288144	17.1759067
10	Iwheel012	8.246269031	7.452218193	8.56353852
11	Iwheel013	7.195005882	6.463677275	6.511276474
12	Iwheel014	17.60215448	15.97425621	22.30273406
13	Iwheel018	23.6505373	22.07980127	25.25207369
14	Iwheel019	12.16287831	10.98876916	12.76269142
15	Iwheel023	11.46755576	8.541751495	10.61757275

Appendix V Mentee recruitment from April to October 2016

Mentee Recruitment (April to October 2016)	N	%
Number of participant agreed to be contacted about the study	60	
Agreed to participate	15	25%
Denied participating	45	75%

Note. Percentage is calculated based on total number (agreed to be contacted)

Appendix W Form and questionnaire completion

Forms and questionnaires	Completed be mentee $N_{need\text{-}to\text{-}complete}$ / $N_{completed}$ (%)	Complete by mentor $N_{need\text{-}to\text{-}complete}$ / $N_{completed}$ (%)
1. Consent form	15 / 15 (100%)	5 / 5 (100%)
2. Knowledge test #1	15 / 15 (100%)	
3. The 3-cone test #1	15 / 15 (100%)	
4. 6-MPT #1	15 / 15 (100%)	
5. Self-efficacy #1	15 / 15 (100%)	5/ 5 (100%)
6. KMT form #1	15 / 15 (100%)	
7. Peer-session evaluation	15 / 15 (100%)	15/ 15 (100%)
8. Workshop evaluation		5/ 5 (100%)
9. Knowledge test #2	15 / 15 (100%)	
10. The 3-cone test #2	15 / 15 (100%)	
11. Drag Test #2	15 / 15 (100%)	
12. 6-MPT #2	15 / 15 (100%)	
13. KMT form #2	15 / 15 (100%)	
14. Knowledge test #3	15 / 15 (100%)	
15. The 3-cone test #3	15 / 15 (100%)	
16. Drag test #3	15 / 15 (100%)	
17. 6-MPT #3	15 / 15 (100%)	
18. Self-efficacy #2	15 / 15 (100%)	5/ 5 (100%)
19. KMT form #3	15 / 15 (100%)	
20. Exit survey	15 / 15 (100%)	5/ 5 (100%)

Form and questionnaire completion

• Use videos to supplement peer-session training • Add different tools to the tool set including wrenches like a spoke wrench to the tool set as well as high-pressure valves/gauges. • Use a check list to track topics covered • Organize session topics in smaller sections • Offer a rack to position the wheelchair (like ones used in bike shops) to provide better access to the wheelchair components • Address situations where wheelchair adjustment is based on the participant's needs

Appendix X Denied participating

Denied reasons for participation in the study	**N (%)** **N_{total} = 45**
I can participate a mentor but not mentee	3 (6.66%)
I do not have a hand function	2 (4.44%)
I do not have time to participate in this study	11 (24.44%)
I know enough about wheelchair maintenance	7 (15.55%)
I leave Vancouver, and I cannot complete the study	3 (6.66%)
Someone else maintains my wheelchair, and I do not need to do it.	3 (6.66%)
Not interested in the study (no specific reason)	16 (35.55%)

Appendix Y Peer-session summary

Time spent and task complete	N (%) (N_{mentee}=15)
Peer-session time allocation	
1. Started on-time	10 (67%)
2. Did not start on-time	5 (33%)
3. Finished on time	4 (27%)
4. Session was more than 3-hr	4 (27%)
5. Session was less than 3-hr	7 (47%)
Topic covered	
9. Tools & suggested supplement	12 (80%)
10. Bearings	15 (100%)
11. Wheel lock	15 (100%)
12. Toeing error	15 (100%)
13. Caster stem	14 (94%)
14. Cleaning	8 (53%)
15. Lubrication	9 (60%)
16. Tires	6 (40%)
Time for all selected topics	
1. One peer-session was enough (<3 hours)	3 (20%)
2. One peer review session was needed, but more than three hours was required.	11 (74%)
3. Multiple peer-sessions needed	1 (6%)
Topic takes more than 30 minutes	
1. Tools & suggested supplement	0 (0%)
2. Bearings	15 (100%)
3. Wheel lock	4 (27%)
4. Toeing error	5 (34%)
5. Caster stem	2 (13%)
6. Cleaning	2 (13%)
7. Lubrication	2 (13%)
8. Tires	0 (0%)
Peer mentoring completed by Masters candidate	**N (%) (N_{mentee}=15, N_{mentor}=5)**
Mentor participation	
1. Mentor explained the goals	15 (100%)
2. Mentor was able to reach the goals	13 (87%)
3. Mentor was able to answer the mentee's questions	10 (67%)
Mentee participation	
1. Mentee followed the mentor's instructions	14 (93%)
2. Mentee was able to explain the selected task, which was taught in the session.	9 (60%)

3. Mentee was able to do the selected task, which was taught in the session.	7 (47%)
Mentee's helper participation 1. Mentee brought helper to the peer-session 2. Mentee's helper assisted the mentee. 3. No helper	 1 (6%) 1 (6%) 14 (93%)
Training 1. All the selected maintenance skills taught during the peer-session 2. Mentor asked mentee to do the selected task by him/her-self	 10 (67%) 10 (67%)
Learning 1. Mentee understood the reasons behind the selected task/topic	 15 (100%)
Problems during the peer sessions	**N (%)**
2. Mentor did not review learning documents 3. Mentor didn't demonstrate/fix anything on manual wheelchair 4. Mentee didn't ask question 5. Mentee's helper was over involved 6. Mentor did not cover all the selected topic	7 (47%) 5 (33%) 0 (0%) 0 (0%) 1 (6%)
Improvement to the peer sessions	**N (%)**
1. More tools and lubrication needed to demonstrate during peer-session 2. We need different types of wheelchair and parts in the session. 3. Use video in the session to illustrate task completion	9 (60%) 2 (20%) 2 (13%)

Appendix Z Standardized response mean

Standardized response mean (Luiz & Almeida, 2012) calculated for Chapter 4 assessments:

Formula: **[Mean ($X_{Initial} - X_{Final}$)] / $SD_{Difference}$**

Test name: The wheelchair maintenance knowledge test

ID	First visit	Second Visit	Delta
iwheel001	15	24	9
iwheel002	13	20	7
iwheel003	20	23	3
iwheel004	6	22	16
iwheel005	16	23	7
iwheel006	15	18	3
iwheel007	12	25	13
iwheel008	27	30	3
iwheel010	12	15	3
iwheel012	13	20	7
iwheel013	12	23	11
iwheel014	13	21	8
iwheel018	21	27	6
iwheel019	15	19	4
iwheel023	10	20	10
Average	14.67	22.00	7.33
SD	5.00	3.70	3.96
Effect size	1.47		
standardized response mean (SRM)	1.85		

Test name: The 3-cone test

ID	First visit	Second Visit	Delta
iwheel001	**15.84**	**14.53**	**-1.31**
iwheel002	**16.65**	**17.11**	**0.46**
iwheel003	**20.71**	**18.54**	**-2.17**
iwheel004	**35.8**	**31.79**	**-4.01**
iwheel005	**18.93**	**18.22**	**-0.71**
iwheel006	**29.47**	**25.71**	**-3.76**
iwheel007	**32.42**	**28.32**	**-4.1**
iwheel008	**15.14**	**14.87**	**-0.27**
iwheel010	**18.66**	**17.6**	**-1.06**
iwheel012	**18.16**	**17.26**	**-0.9**
iwheel013	**27.88**	**22.76**	**-5.12**
iwheel014	**16.71**	**18.39**	**1.68**
iwheel018	**24.83**	**27.44**	**2.61**
iwheel019	**17.31**	**16.93**	**-0.38**
iwheel023	**18.45**	**18.76**	**0.31**
Average	21.80	20.55	**-1.25**
SD	6.60	5.32	**2.22**
SRM	-0.56		

Test name: The self-confidence test

Confidence in doing yourself

	Confidence in doing yourself		
	Pre	Post	Delta
I-WHEEL001	84.00	92.86	8.86
I-WHEEL002	31.86	71.00	39.14
I-WHEEL003	100.00	100.00	0.00
I-WHEEL004	21.29	70.57	49.29
I-WHEEL005	81.14	99.14	18.00
I-WHEEL006	63.00	87.43	24.43
I-WHEEL007	14.29	62.86	48.57
I-WHEEL008	85.00	98.57	13.57
I-WHEEL010	28.14	40.71	12.57
I-WHEEL012	48.57	100.00	51.43
I-WHEEL013	3.00	80.00	77.00
I-WHEEL014	70.71	94.29	23.57
I-WHEEL018	78.86	99.71	20.86
I-WHEEL019	25.29	87.14	61.86
I-WHEEL023	18.57	93.29	74.71
Average	50.25	85.17	34.92
SD	31.62	17.23	24.41
Effect size	-1.10		
standardized response mean	1.43		

Confidence in teaching others

	Confidence in teaching others		
	Pre	Post	Delta
I-WHEEL001	82.00	93.86	11.86
I-WHEEL002	37.29	75.86	38.57
I-WHEEL003	79.29	98.57	19.29
I-WHEEL004	0.00	54.29	54.29
I-WHEEL005	55.57	92.43	36.86
I-WHEEL006	52.71	70.29	17.57
I-WHEEL007	0.00	54.29	54.29
I-WHEEL008	80.71	98.57	17.86
I-WHEEL010	15.86	38.86	23.00
I-WHEEL012	40.00	81.43	41.43
I-WHEEL013	32.57	83.43	50.86
I-WHEEL014	71.43	96.43	25.00
I-WHEEL018	80.71	99.43	18.71
I-WHEEL019	36.86	64.43	27.57
I-WHEEL023	2.43	84.14	81.71
Average	44.50	79.09	34.59
SD	30.45	19.03	19.23
Effect size	-1.14		

standardized response mean (SRM)	1.80		

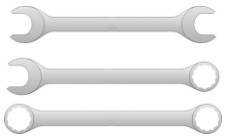
Appendix AA Wheelchair maintenance manual (by Ian Denison)

The Right tool

Many clinicians go through their workweek without touching a tool. They see something that needs doing on a chair, issue a decree, and magically the work is done. There are others who can't wait to get their hands dirty; they feel there is not a chair on the face of the earth that wouldn't benefit from their attention. Between the two, lays the technician's nightmare, the ones they fear, the ones who know enough to do damage - and not enough to realize it.

This information will help you understand tools commonly used on wheelchairs and perhaps endear yourself to the technicians you work with, as a therapist who is kind to chairs.

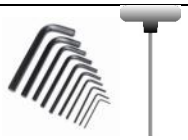
A question I am routinely asked is "What tools do I need to make the most common adjustments. The answer is constantly changing depending on the vagaries of the market. Here is my best estimate.

Tool	Appearance	Fastener	Imperial	Metric	Comment
Wrench			$^{7}/_{16}$" ½" ¾"	10mm 11mm 12mm 13mm 19mm	(11mm and 19mm are the same as $^{7}/_{16}$" and ¾")
Sockets			$^{7}/_{16}$" ½" ¾"	10mm 11mm 12mm 13mm 19mm	(11mm and 19mm are the same as $^{7}/_{16}$" and ¾")

Wrenches and sockets are the basic tool for chair maintenance. Often you need to have two of each size, one to hold the bolt head and the other to turn the nut (or vice versa). If you have a socket and ratchet of the appropriate size you can use it instead of one of the wrenches. Make sure you use the proper size wrench Only use adjustable wrenches when you don't have a real one in the proper size.

Adjustable wrench			0-1$^{1}/_{4}$”	Seem like a great idea but should only be used when a proper size wrench or socke is unavailable. If the wrench is not used properly the bolts or nuts will round off.

Slide wrench all the way on to nut, (unlike photo) so there is full contact at the back of the jaws. Then tighte the wrench thumbscrew so there's no play at all in the jaws. Always turn the wrench handle toward the lowe (or fixed) jaw, never away from it.

Allen Keys			$^{1}/_{8}$” $^{5}/_{32}$” $^{3}/_{16}$”	2mm to 8mm	Metric and Imperial are hard to distinguish. Ensure a reall good fit between wrench and bolt to prevent rounding.

Allen bolts are popular fasteners with wheelchair manufacturers and a set of metric and imperial keys will help in making adjustments. The most common Allen keys are “L” shaped and both ends fit the same size bolt. Stick the short end in and you have added leverage for loosening stuck bolts. Sticking the long end in will allow you to remove loose bolts quickly. If you don’t mind carrying quite a few tools “T” handle Aller keys are nice to use. To condense your tool bag get some Allen bits to fit your multi bit screwdriver. Or get hand tool with keys arrayed like blades in a Swiss Army knife. The ball ended ones are very versatile, sinc they can be inserted from an angle rather than just straight on.

Screw driver			Slotted Phillips #2 Pozi drive Robertson #2 Torx - T15, T20, and T30	Phillips and Pozi drive look very similar but a not interchangeable. Phillips are the most difficult to ensure prop fit.

A multi bit screwdriver is a compact way of lugging around various screwdrivers. As with all fasteners ensure the bit is the same type and size as the screw. When using a screwdriver always push the screw hard into the material it penetrates even when unscrewing.

Tire pump and gauge			A hand pump with a gauge will allow you to fix slipping wheel locks more often than a wrench. You can also make the chair easier to push and the tire le likely to puncture by keeping pressures at the value marked on the sidewall. A separate gauge can be us but some people lose half the air when using it

A foot pump, compressor, or special high-pressure hand pump is needed to inflate tires to values over abou 50 psi. Gas stations have airlines that will fit Schraeder valves but not the skinnier Presta valve, which neec an adapter to be used. I do not recommend Presta valves for any wheelchairs - other than racing ones.

Other useful tools

Pliers	Utility knife	Tape	Inclinometer	Nylon ties	Duct Tape	Sticky Velcro	Gloves	Hand wash
								

- Needle nose pliers don't have a primary use on a chair but are useful tools that can perform a number of tasks on a wheelchair; including pulling stubborn upholstery, lining up holes, cutting tie wraps etc.
- A utility knife is also handy to have; some types have snap off blades and are easy to keep sharp.
- Tape measures allow you to make precise measurements
- Inclinometers measure angles e.g., caster housing angle, back angle, seat dump, camber etc.
- Nylon ties allow semi-permanent fixes and help tidy loose cables.
- I don't think duct tape needs its praises sung here. However, don't use it as a long-term solution since the tape deteriorates quickly and makes a mess.
- Saran wrap (not shown) around the push handle part of a cane back facilitates upholstery removal.
- Self-adhesive Velcro™ is also useful for mounting switches and securing seating elements.
- Don't forget to keep your hands clean, some chairs can get pretty disgusting.

In this context nuts are metal bits that go on the end of a bolt. Regardless of whether a nut is metric or imperial there are three common types found on wheelchairs. Four other types that you may come across are also described.

Name	Picture	Comment
Hex nut		Most common fastener where loosening is not likely to occur. Nut thread and diameter have to be matched to the bolt in order to work.
Acorn or Cap nut		A nut with a domed top to prevent contact with the external thread. Particularly useful on footrests and armrests. Nut projects out a little, but there are no sharp edges.
Nylock nut		Very common on wheelchairs. A nylon insert at the top of the nut provides a locking feature. The nylon insert, it is claimed, helps to seal the bolt thread against seepage of water, oil, petrol, paraffin or other liquids such as urine. It is meant to be used only once. I use them as long as I can't turn them by hand.
Wing nut		A nut with 'wings' for hand tightening.
Flange nut		A nut with a built in washer, not as good as a real washer since it turns with the nut.
Jam nut		A nut with a reduced height. May be a regular hex or nylock nut.
Tee nut		A nut designed to be hammered into wood to create a threaded hole.

Bolts

Welds are used to hold parts of a structure together in a permanent way. Welding is usually the cheapest, strongest, and lightest way of connecting two pieces of metal. Nuts and bolts are used to hold parts of the wheelchair together in a permanent or semi-permanent way. Depending upon the specific wheelchair; the fasteners used may be metric (mm) or imperial (inches). Some North American chairs are imported from Europe and modified for the local market by the addition of footrests or armrests. These hybrids often have metric fasteners for the frame and imperial fasteners on the North American bits. So be warned you may have both metric and imperial nuts and bolts on the same chair, don't take anything for granted.

Bolts usually, but not always have identifying markings on the head. The most common markings indicate the strength of the bolt and also if it is metric. Never use a lower grade bolt to replace a higher one.

Imperial (SAE) Bolt	Relative Strength	Metric Bolt
 Grade 1 or 2	60	
 Grade 5	120	
 Grade 8	150	
Stainless and Titanium markings vary. Most are non-magnetic	100	Stainless and Titanium markings vary. Most are non-magnetic

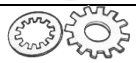
Bolt size

The size of the specific bolt is a indicated by a series of numbers here is the key to the code.

SAE Imperial	What it refers to		Metric
5/16 x 18 x 1-1/2	Bolt description		M8 - 1.25 - 25
5/16	Outside thread diameter (inches)	Outside thread diameter (mm)	M8
18	Number of threads per inch	Distance between threads (mm)	1.25
1-1/2	Length of bolt (inches)	Length of bolt (mm)	25

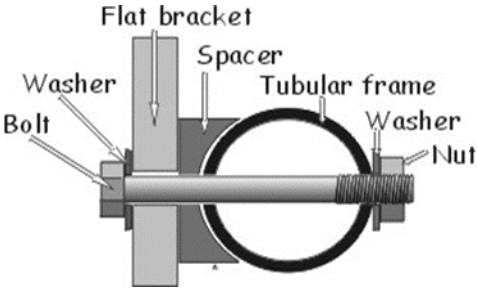
Washers

Circular discs of metal with a hole in the middle are found in many locations on a wheelchair. They protect the soft aluminum frame, perform a spacing function for camber and offsets and help to stop nuts from loosening over time.

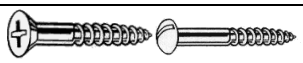
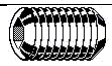
Name	Picture	Comment
Flat washer		A flat washer used to distribute load and protect softer material.
Fender washer		An oversize flat washer used to further distribute load especially on soft material.
Finishing washer		A washer used to obtain a 'finished' look. Usually used with oval head screws on upholstery.
Split lock		The most common style of washer used to prevent nuts and bolts from backing out.
Internal/External tooth washers		A washer with 'teeth'. Used to prevent nuts and bolts from backing out. Not used much on wheelchairs since it tends to chew up the soft aluminum. If used on a wheelchair protect the frame with a flat washer.

Placement of nuts bolts and washers

In wheelchairs it is not unusual to find spacers shaped in such a way that a flat bracket can be mounted to a tubular frame. In this instance the proper order for assembly is as follows:



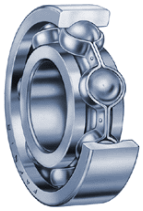
Other fasteners you may come across

Name	Picture	Comment
Wood screw		Screws with a smooth shank and tapered point for use in wood. Found in custom seating systems.
Machine screw		Screws with threads for use with a nut or tapped hole, typically used to secure seat upholstery.
Sheet metal screw		Screws with a point for use in sheet metal. Often used to keep back sling attached to cane.
Set screw		Used to hold things in place once they are positioned properly.

Adjusting Bearings

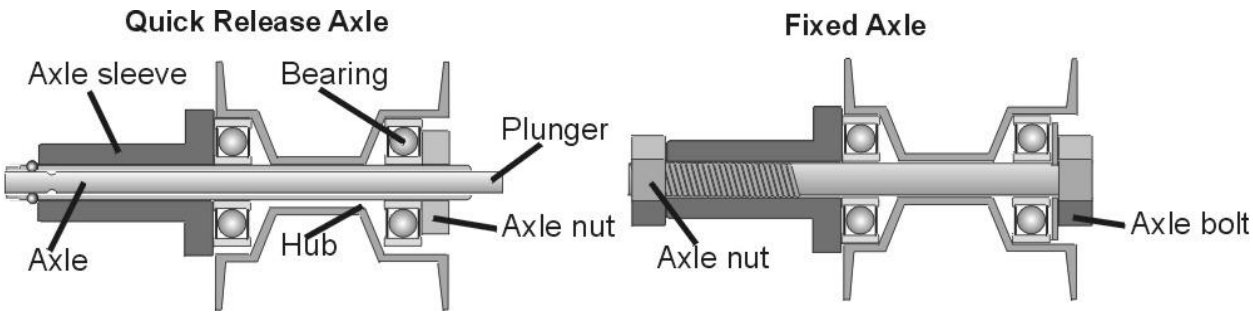
One of the most common service tasks is to check and adjust or replace the bearings. It is at the bearing - not the wheel that actual movement occurs. Servicing bearings is relatively simple; identifying the need for service is even easier. The rewards realized from replacing a seized bearing make learning a little mechanics very worthwhile.

A manual wheelchair has twelve bearings. Wheel bearings (4), caster bearings (4), and caster stem bearings (4). All the bearings are straight bearings and are different to bike wheel bearings which have a cup and cone design that requires pre-loading when adjusting them.

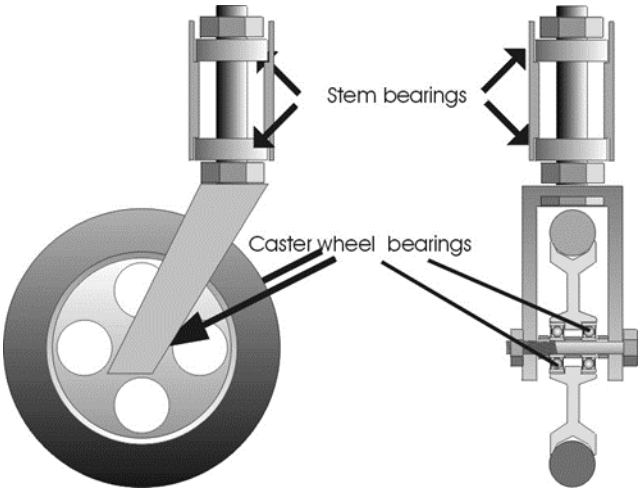


Wheel, caster and stem bearings perform different tasks and need to be treated slightly differently

Wheel bearings carry the majority of the weight and need to spin with minimal resistance. There is often a quick release mechanism built into the axle that cannot be adjusted with the same precision as fixed axles.



Caster bearings are like smaller wheel bearings except they are much closer to the floor and as such are most likely to pick up hair and other contaminants. The hair needs to be removed on a regular basis particularly if there are furry pets around. The easiest way to clean the caster assembly is to remove the wheel, take out the hair, wipe it off, and then reassemble. Tightening the axle nut is the same as for the wheel bearing.



Unlike wheel and caster bearings, stem bearings don’t really spin, they just turn. They can be adjusted to be a little tighter than previously described for wheels. This will help to prevent caster flutter. Some chairs use bushings at the top instead of bearings. Bushings are basically discs of low friction material, like polypropylene or bronze with a hole for the axle. They are cheaper than bearings but tend to wear quicker. A bearing can often be used to replace a worn bushing.

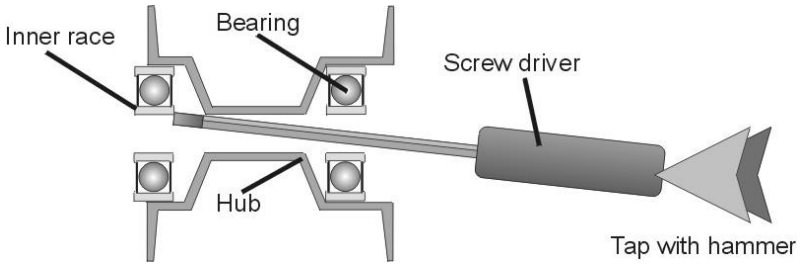
Testing Wheel and Caster Bearings

1. Lift one side of the chair off the ground.
2. Spin the wheel and let it rotate freely to a stop. (This is not the wheel of fortune; a gentle spin is enough.)
3. If it slows and stops dead, it is too tight.
4. If the wheel slows and rotates backwards slightly the bearing is not being compressed, however it could be too loose.
5. Grasp the tire and wiggle it in and out to see how much play there is at the axle, less is better.
   NB. Quick release wheels will always have a little play.

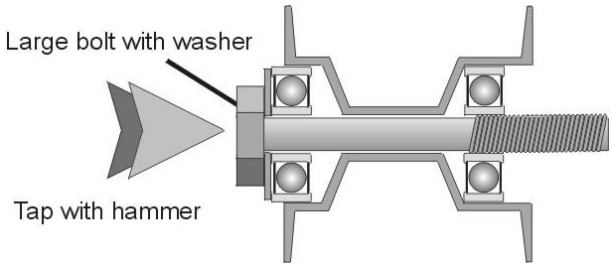
Removing and Installing Wheel Bearings

1. If you are replacing bearings you can use a screwdriver to knock out the old ones.

   However, a screwdriver can damage the inner race. If you intend to reuse the bearings find something with a more forgiving end or be gentle and tap all the way around the race, easing the bearing out slowly.



2. Repeat for the other side
3. Seat the new bearing using the largest bolt that fits in the axle hole and a washer big enough to reach the outer race.
4. Repeat for the other side.
5. Go to step 2 in the testing section.
6. Adjust the axle play to the smallest amount possible



Adjusting Axle Play (fixed axle)

1. Tighten the axle bolt until the wheel does not spin freely.
2. Back off ¼ turn at a time and spin the wheel until it just counter rotates after stopping.
3. Tighten the axle nut.

Adjusting Quick Release Axles

1. Check the play in the wheel and make sure it spins freely.
2. To adjust the play the wheel must be removed.
3. The axle nut is ¾" and is easiest to adjust with a socket.
4. The axle has to be held with either a $^{7}/_{16}$" wrench on the flat spots near the other end or a ½" wrench in line with the balls.
5. Keep tinkering with the length of the axle until the wheel has the least amount of side play when the plunger still pops out.

Compromised bearings can significantly increase the energy required to propel a manual chair.

The slow onset of bearing deterioration makes it a very common occurrence because the user doesn't recognize the microscopically small increases in energy expenditure from day to day.

Half an hour and $100 worth of bearings can make an incredible difference to someone's manual wheelchair propulsion efficiency.

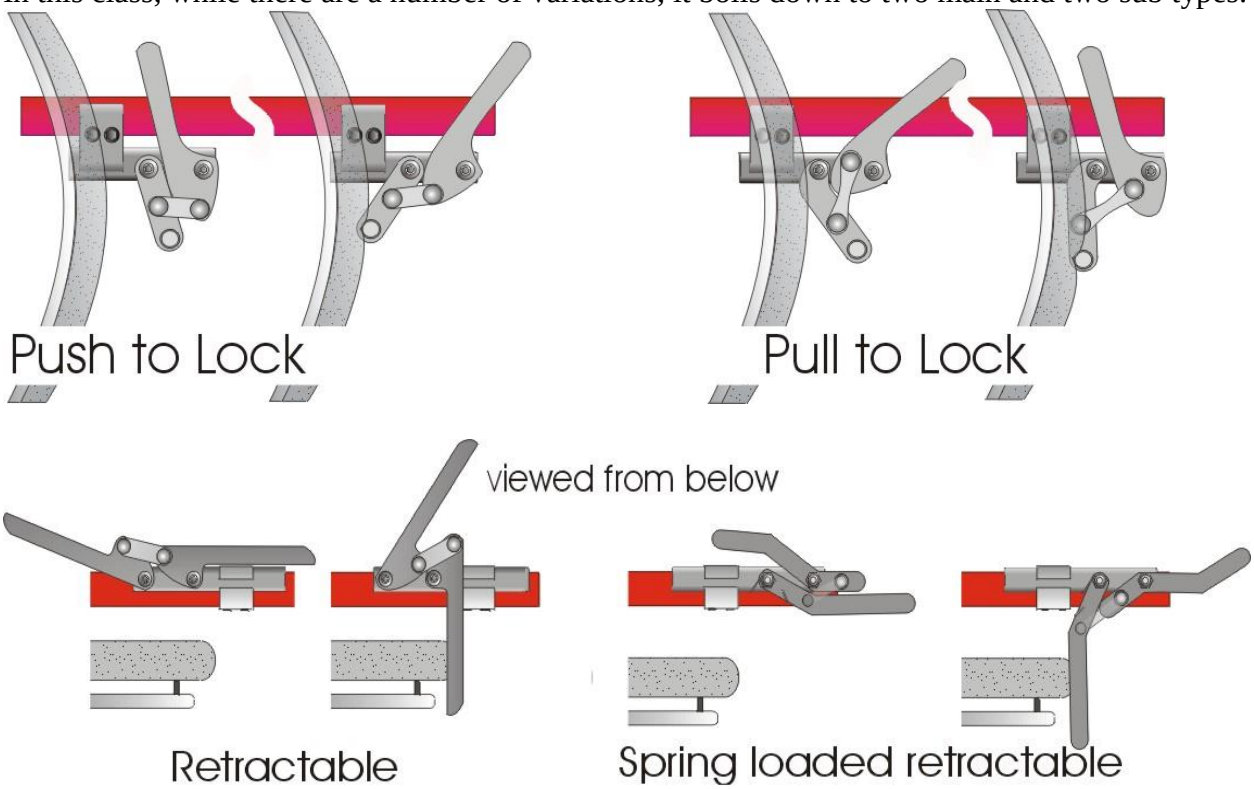
Wheel Lock Adjustment

Wheel Locks used to be called brakes until a lawsuit was launched by someone who used the device to slow themselves down and fell out of their chair. They could have been called parking brakes but wheel locks won.

This information only covers wheel locks that work by putting pressure directly on the tire but since that covers about 98% of the wheelchairs you are likely to see it should be enough. Other wheel locks are available that act on the hub either directly or via a cable and or disc. They are uncommon and not covered here.

Types of Wheel Lock

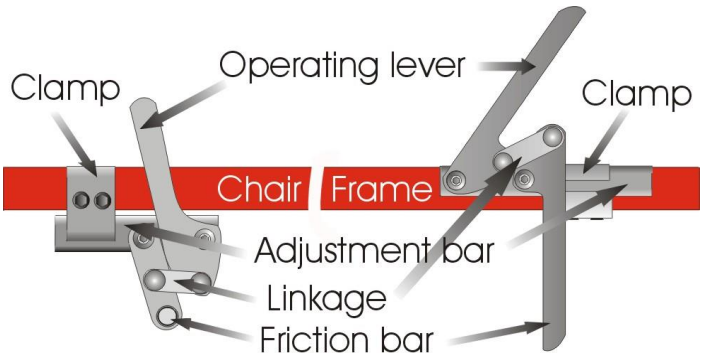
In this class, while there are a number of variations, it boils down to two main and two sub types:



Reasons for wheel locks not working	Solution
Pneumatic tires deflated	Inflate tires
Worn down solid tires	Replace tires and /or adjust wheel lock position
Worn friction bar on lock	Adjust wheel lock position
Axle position was adjusted	Adjust wheel lock position
New wheels and / or tires	Adjust wheel lock position
Wheel lock linkage sloppy	Adjust linkage tension

With pneumatic tires always check inflation. Recommended pressure is marked on the tire wall.

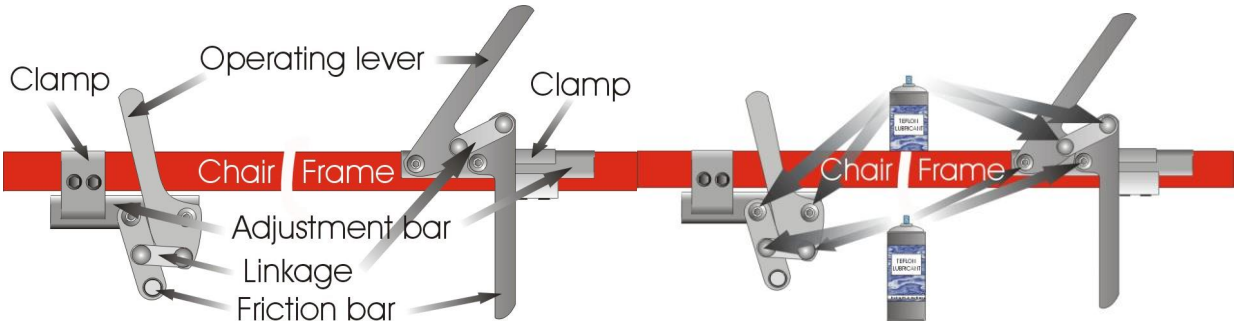
1. Apply the wheel lock using the operating lever and determine how far the friction bar needs to move.
2. Release the wheel lock.
3. Loosen both bolts securing the clamp to the chair frame.
4. Slide the adjustment bar the appropriate amount.
5. Tighten the bolts
6. Apply the wheel lock.
7. Check to make sure the wheel doesn’t rotate, and the chair user can operate it.



Adjusting the Linkage Tension

Most wheel locks have four pivot points. There are two on the adjustment bar and two on the linkage that connects the operating lever to the arm that applies friction to the tire. All pivot points have to allow free movement in one plane only. On better wheelchairs a low friction washer is used between each metal component. As the components wear, they can either seize up or get sloppy depending on circumstances. In either case cleaning, lubrication, and adjustment will help.

The two pivot points on the adjustment bar are generally bolts and nylock nuts. The two pivot points on the linkage can be either bolts and nylock nuts, or rivets. If they are rivets, they cannot be adjusted. If they are bolts, they can.

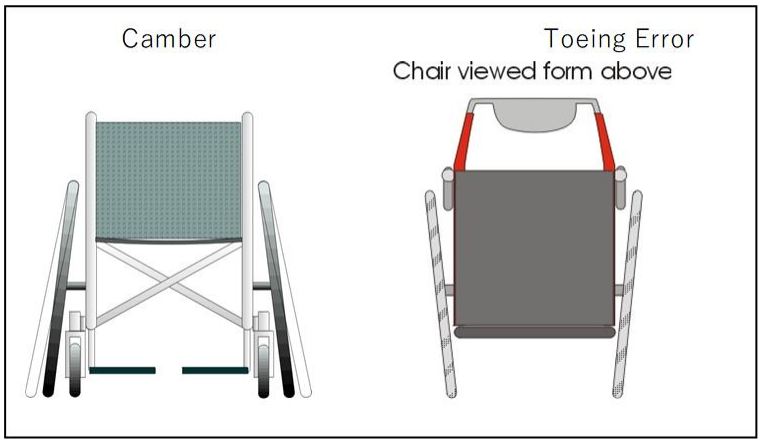


1. Loosen bolts.
2. Spray anti-friction washers with a Teflon™ lubricant and wipe off the over spray.
3. Tighten bolts until snug.
4. Back off a little at a time until the mechanism moves with minimal resistance.
5. Adjust the wheel lock as described earlier.

If the wheel locks become sloppy quickly, replace the nylock nuts and / or use Loctite on the bolt threads.

Tracking Adjustment

Wheel camber is the name given to a situation where the wheels viewed from the front are not parallel. Camber has a number of benefits as well as drawbacks. Toeing error is the name given to a situation where the wheels viewed from above are not parallel; toeing error has no benefits, only drawbacks.
Toeing error is the same as camber except rotated through 90 degrees.



In theory, without camber a wheelchair would never need to be checked for toeing error regardless of the adjustments made. But since we discovered the benefits of camber; pretty well all high-end chairs have a number of different camber settings available. With the availability of camber comes the need to compensate for toeing error that may be induced by a change in wheel height or seat angle. Since there is a mechanism for correcting it, the same mechanism, if left out of adjustment can create it. One degree of toeing error increases energy expenditure by 50% and 2 degrees = 150%. Toeing error should be checked and minimized on all chairs. Even if you don't get the wrenches out to fix this problem simply alerting the client to it can save him loads of shoulder wear and tear if he takes time to have it fixed.

Benefits of Camber

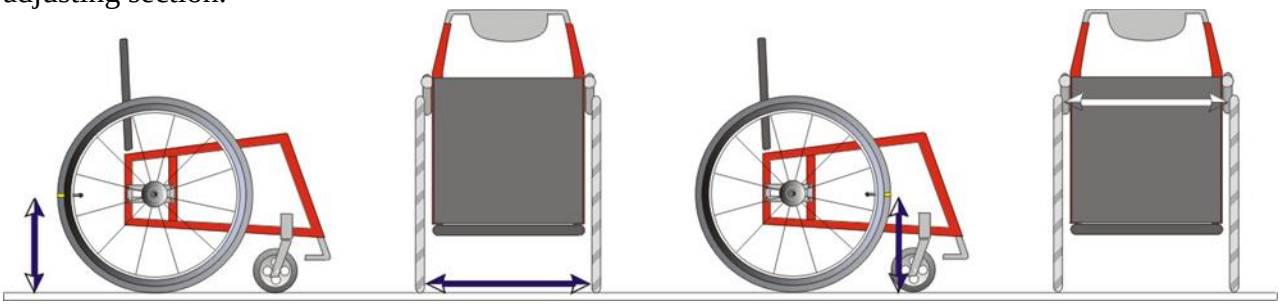
1. Decreased tendency to turn down hill
2. Hand protection through doors
3. Increased stability turning at speed
4. More natural shoulder action

Drawbacks of Camber

1. Chair wider
2. Toeing error in wheelie position
3. Slight increase in tire and bearing wear

Measuring

1. Make sure the chair is on a flat smooth surface.
2. Measure the vertical height of the axle from the ground.
3. Draw a mark on the tires at the same height. Or move the wheel until the valve is there.
4. Measure the horizontal distance between the insides of the tires at the height of the mark.
5. Rotate both wheels through 180 degrees so the mark is at the correct height from the ground again.
6. Measure the horizontal distance between the insides of the tires at the height of the mark.
7. Compare your results from step 4 and 6; they should be identical. If not go on to the adjusting section.



Adjusting toeing on a chair with a camber bar.

1. Rotate the wheels so the marks are axle height from the floor at the back.
2. Loosen the bolts holding the camber bar.
3. Rotate the bar until the wheels are parallel. (If the camber bar has a built in spirit level; simply rotate the bar until the bubble is in the middle.)
4. Check the width at the back. E.g. if you measured 24” and 25” for step 4 and step 6 (above) respectively you had a 1” toeing error.
5. The error can be eliminated by rotating the bar until the distance is 24.5”
6. Check to make sure the wheel locks still work.

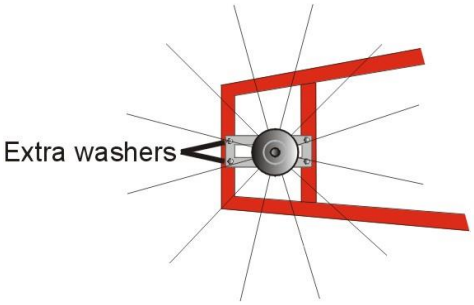
Adjusting toeing on a chair with a camber plate.

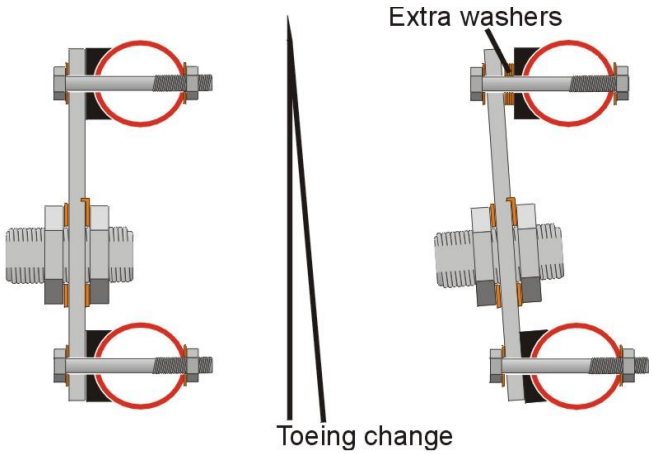
This is way more involved than adjusting a camber bar equipped chair. Allow yourself at least half an hour for the job. You will need two sets of washers adding up to 1/8” thick each. The aforementioned measurements suggest the chair is toed out. You will therefore need to move the camber plate out at the back by placing washers between the spacer and the plate. Work only on one side at a time so you have a reference to help you remember where everything goes.

1. Lay the chair on its side.
2. Remove the upper wheel.

3. Loosen the two nuts securing the camber plate at the front.
4. Remove the two nuts at the back of the camber plate and pull the bolts out. Take care not to displace any washers already in place.
5. Add the appropriate number of washers between the camber plate and spacer.
6. Reassemble, taking care to snug up all four nuts equally before tightening them.
7. Make sure you have no parts left over; use the untouched side as your reference.
8. Now do the same thing to the other side.
9. Measure the toeing. (If it is still off - go to step 1. and feel free to curse)

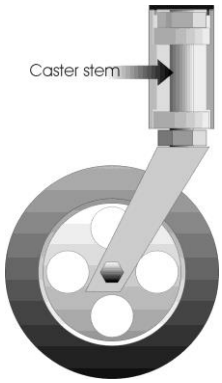
Adjust the wheel locks.

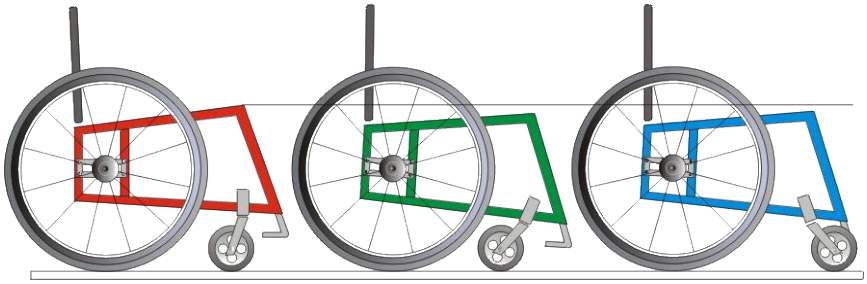




Caster Stem Adjustment

Caster stems that are not vertical cause a number of problems. If the stem leans forwards at the top (middle diagram) the chair is difficult to turn and the knees are lower wheeling forwards than when wheeling backwards. If the stem is leaning backwards at the top, the chair is difficult to keep in a straight line and the knees raise up higher when rolling forwards. Also whenever the wheeler stops the chair will roll backwards a little.





Changes that can affect caster stem angle include:
Rear wheels

- Changing wheel size
- Significantly changing camber
- Moving up or down on camber plate to change seat angle

Casters

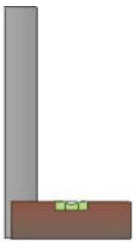
- Changing fork or wheel
- Hitting an obstacle

Caster stems must be kept as vertical as possible. Some chairs do not allow any angle adjustment, relying on different length fork and caster wheel size to keep the stem vertical. Of the chairs that do allow for angle adjustment there are a number of different ways of accomplishing the task. There are also a number of different ways to test if the stem is vertical.

Tools

All methods of measuring caster stem angle require that the floor is flat and level. Then a reference point on the caster fork and or stem housing is compared to see if it is either perpendicular or parallel to the floor. Tools commonly used include:

1. Tri square
2. Spirit level
3. Angle finder

1. 

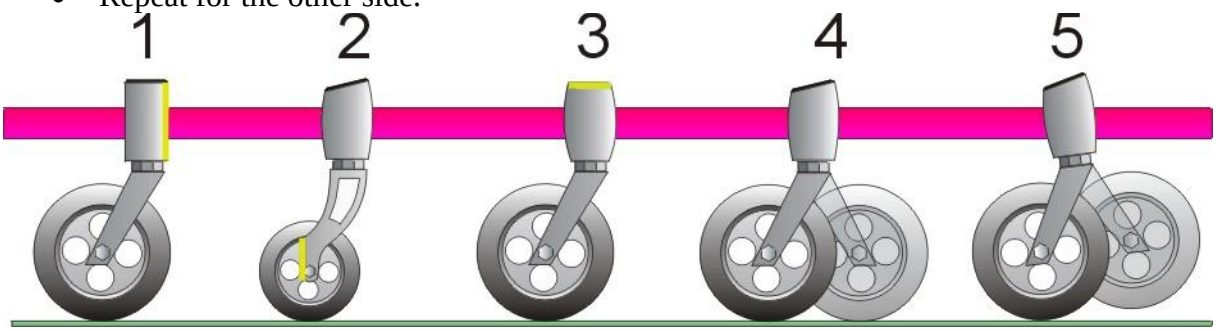
2. 

3. 

This is not an exhaustive list; there are other tools that can be used to indicate the angle of the stem relative to the ground.

Measuring

- Ensure the chair is on level ground.
- Identify a surface on the caster stem or caster fork that is either parallel or perpendicular to the stem.
- Measure the deviation from vertical or horizontal.
- Repeat for the other side.

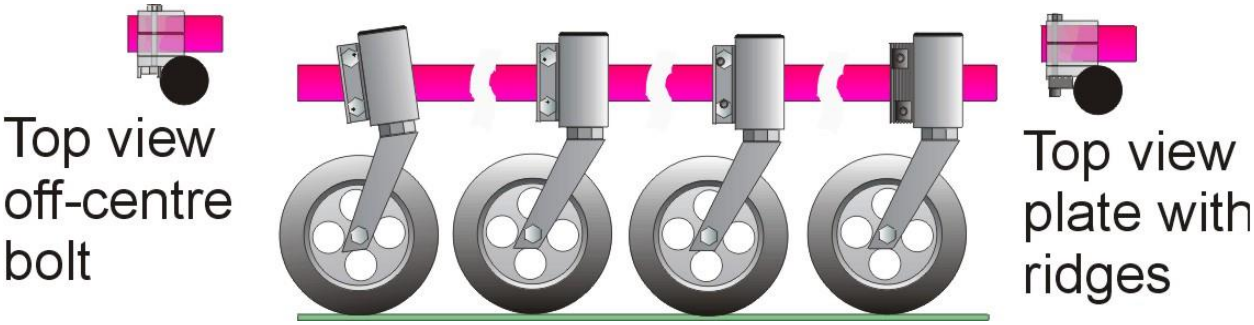


Example 1 – The caster housing should be vertical.
Example 2 – The trailing edge of the fork should be vertical.
Example 3 – The top of the caster housing should be horizontal.
Example 4 & 5 – When there are no obvious horizontals or verticals; rotating the caster 180 degrees from the trailing to the leading position is an easy way to tell if the stem is vertical. The caster wheel should always be just touching the surface. If the stem is not vertical the wheel will lift or the front of the chair will rise up. (5)

Adjusting

The exact method of adjusting caster stem angle varies depending on the particular model.

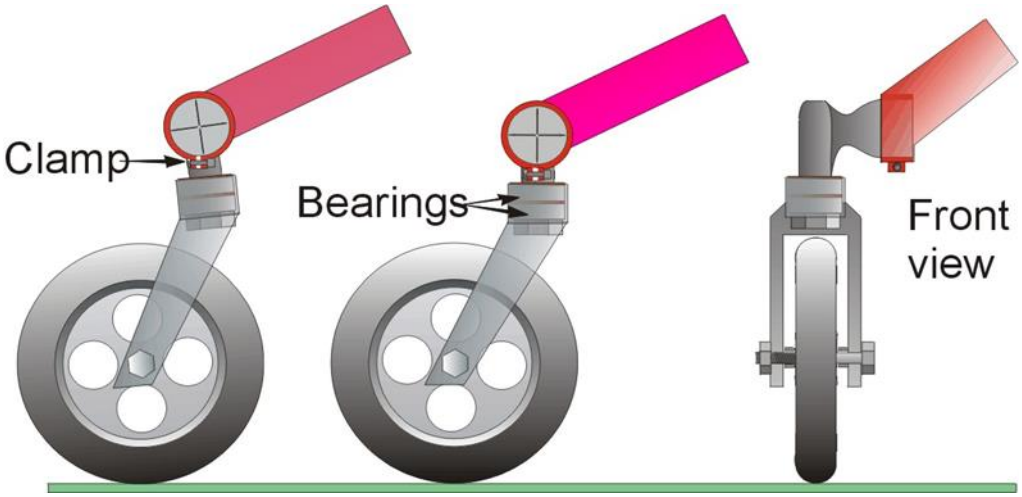
Off center bolt, washer, or ridged plate



Either a bolt with an off center shaft, a washer with an off center hole, or a plate with ridges is used to accomplish caster stem alignment.

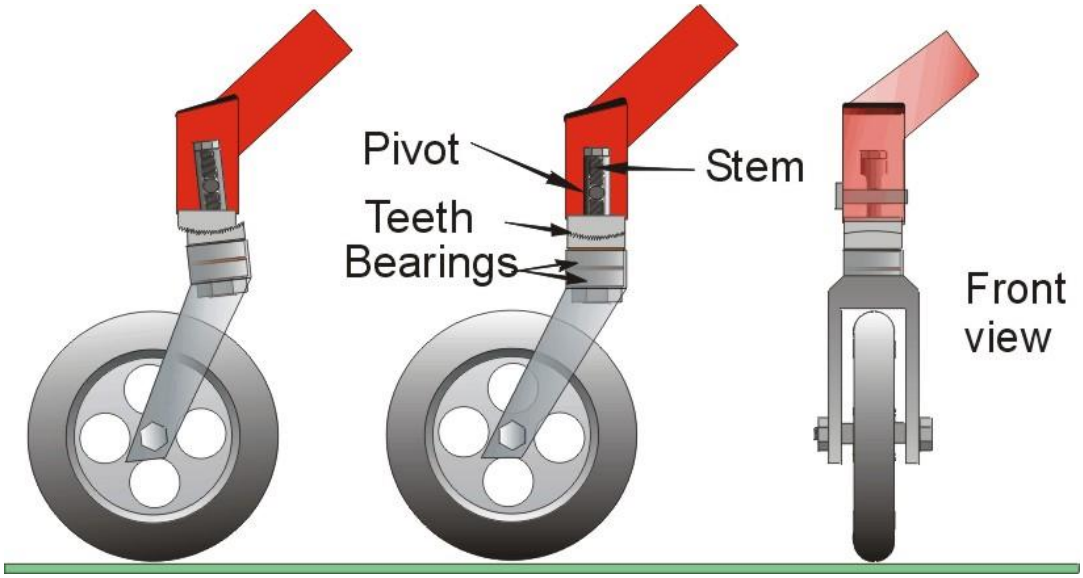
1. Loosen the nuts on the inside of the caster stem mounting bracket.
2. Rotate the top and bottom bolts, washers or move the plates until the stem is as close to vertical as possible.
3. Tighten the nut and check the alignment.
4. Repeat on the other side

Clamp Style



1. Loosen the nut clamping the caster to the frame.
2. Rotate the caster assembly until the stem is vertical.
3. Tighten the nut and check the alignment.
4. Repeat for the other side.

Tooth Style



1. Remove the dust cap from the top of the caster stem housing.
2. Loosen the bolt sufficiently to let the teeth become disengaged from each other.
3. Rotate the caster assembly until the stem is vertical.
5. Tighten the nut and check the alignment.
4. Repeat for the other side.

There are other mechanisms by which the caster stems are adjusted. If you are ever in doubt as to how they work keep one side intact, so you always have a reference to refer to for reassembly.

Lubrication

Cleaning

Wheelchairs really benefit from a good cleaning. Mild soap and water is recommended for the frame and non-absorbent bits. In fact you can clean it as you would a car. Finishing with car polish will add a layer of protective wax to help it to stay clean. If the chair hasn't been cleaned in ages dampening it for a while should soften the accumulated grime. Remember water isn't going to hurt the chair unless it stays wet for days on end. Upholstery can be wiped down with a damp cloth or use fabric cleaning liquids. Cushions need to be dealt with according to the manufacturers' guidelines.

Lubricate where two parts of a chair move relative to each other. Dry lubricants like Teflon™ and graphite tend to be the most user-friendly. They leave a dry film on the material that displaces water, inhibits corrosion, and provides a smooth slippery interface between the two surfaces. Most are compatible with the plastics and metals found on wheelchairs. Teflon dries clear and graphite dries black. Owner's manuals will give a comprehensive list of areas to lubricate.

Over-lubrication can be a problem on wheelchairs. This occurs when too much grease or oil is applied. Dirt, hair and other nasty stuff sticks to the surface and can actually do more harm than good by trapping abrasive particles, not to mention getting the icky stuff on clothing. Whenever lubricants are used bear this in mind and wipe off over spray.

Quick release axles

If the wheels are not removed on a regular basis the axles tend to seize up. Maintenance of these items is very easy. It needs only to be done on a monthly basis at most.

1. Remove the axle.
2. Wipe it off with a cloth dampened with WD40.
3. Lubricate with dry Teflon™ spray or if you only have WD40 use it and wipe off the extra. (You can even use Pam cooking spray if you have nothing else.)
4. Dampen a cloth with WD40 and wipe off any accumulated dirt from the bearings.
5. Replace the wheel and ensure the quick release plunger extends fully to secure the wheel.

Bearings

Almost all wheelchair bearings are sealed bearings, which keep out foreign bodies and keep the lubricant inside. The lubricant eventually breaks down and at that time bearing wear increases dramatically.

Spraying WD 40 on the outside of a bearing and wiping it off will not hurt the bearing and will help clean it. Smearing grease on the outside will not help the bearing, it will however attract dirt and abrasive material, which could damage the bearing and certainly make the chair less appealing.

If you want to lube a bearing you have to very carefully remove one of the seals (black bit) using a sharp pointy tool like a pin or knife to expose the cage (shiny bit). Wash the bearings in a solvent and let thoroughly dry before repacking with grease and replacing the seal. Do not use WD40 as a lubricant for bearings, it is too thin and will actually accelerate bearing wear. You can use it as a solvent to clean out the old grease though.

Fixing a flat tire

The only drawback to pneumatic tires is they can lose their air. This occurs either over time, or due to a puncture. Air loss occurs naturally at a rate of about 50% in two months, the loss is through the walls of the tube not the valve. If air is lost at a quicker rate you have a puncture.

Most pneumatic wheelchair tires are clinchers, which means they use an inner tube, the air in the tube presses the tire onto the rim and the pressure holds it in place. Air enters the tube through a valve, of which there are two kinds, Schraeder and Presta. The inside of the rim is covered in rim tape so that the nipples of the spokes don't poke holes in the tube. The edges of the tire are lined with wires to hold onto the rim; this is called the bead. The tire must be removed from the wheel to test and fix the tube.

Different Kinds of Flats

A sharp object that sticks in your tire and punctures the tube causes most flats. The second most common type is caused by a pinch, these are called snakebite flats. Snakebites occur when hitting a curb with too little air in the tube. Occasionally a valve leaks and the valve core has to be replaced. If the tube explodes due to an old, weak, or poorly fitting tire the tube and tire must be replaced.

Tools

- A pump compatible with the valve.
We recommend Schraeder valves.
- A tire pressure gauge, one built into the pump is the most convenient.
- Tire levers, which help lift the tire bead over the rim
- A patch kit, with extra patches, rubber cement, and a piece of sandpaper or a buffer

Tire and tube removal

1. Mark the tire next to the valve to help locate the puncture later.
2. Let all the air out of the tire by pressing the little stem in the middle of the valve.(If you have a Presta valve unscrew the top and press it in).
3. Release the bead from the rim all the way around (it tends to stick). Then push the beads in towards the rim well.
4. Unscrew the nut holding the valve to the rim (if it has one). Use the tire levers to ease the tire off the rim. If you can do it without levers that is better. Don’t use a screw driver because it will damage the rim and may make another hole in the tube.
5. Pull the tube out of the tire.

Fixing the tube

1. Inflate the tube using the pump.
2. Hold the tube close to your face and listen and feel for the air escaping. This is easier than looking. If you cannot find the puncture submerge the tube in water and you will see the bubbles of escaping air from the puncture.
3. When you find the puncture, scrape the area around it with the buffer (sand paper). This cleans the rubber and roughens it so that it takes the patch better; it also marks where the puncture is so you can find it again when the tube dries.
4. Let the majority of the air out. Cover the area with rubber cement (from the patch kit); make sure that the area covered is greater than the size of the patch. Larger holes need bigger patches. Wait about five minutes for the cement to dry.
5. While the cement is drying, look for the sharp object that caused the puncture. If you use the mark you made on the tire to see how the tube was lined up with the tire, it shouldn't be hard to figure out which section has the offending object in it. Take a piece of cloth and run it along the inside of the tire; it will stick on the protruding object that punctured the tube. Remove the object.
6. When the cement is completely dry. Peel the silver foil off the patch and apply that side to the tire. Rub hard from the center toward the edges so that it sticks really well. Leave

the cellophane on; it can be tricky to remove without damaging the patch and it helps protect the patch.

7. Dust the excess glue with talc or chalk to stop it adhering to the tire.

Replacing the tube and tire

1. Make sure the tape is in place around the rim, it protects the tube from the spoke nipples.
2. Inflate the tube slightly and pack it back into the tire, pushing the valve through the hole in the rim. Make sure the valve stays perpendicular to the rim.
3. Now slide the bottom bead over the rim, this should be easy to do.
4. Ease the second bead over the rim working your way around on both sides towards the opposite side.
5. The last part of the bead will be very difficult to lift over the rim. Make sure the bead where you started is pushed way in to the rim, this will give you a little slacker. Gradually work the top bead up and over the rim taking care not to pinch the tube. If you do, you will have to go back to square one. If possible, try to complete this without using the tire levers to reduce the likelihood of damaging the tube. A little Armor All on the sticking bead can help ease things.
6. When the tire is on, push both beads into the well of the rim all the way around the wheel to make sure the tube isn't pinched.
7. Inflate the tube to the pressure marked on the sidewall.
8. Tires have a reference line that should be the same distance from the edge of the rim all the way around; this ensures the tire is seated properly on the wheel. If it is off center let air out adjust the tire on the rim and re-inflate.

Reducing Rolling Resistance

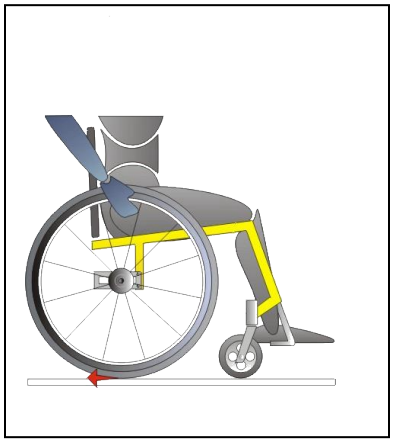
At speeds between zero and two m/s, rolling resistance is the largest force a wheeler has to overcome. At higher speeds, air resistance has a bigger impact. Two m/s is about 7 km/h or $4^1/_2$ mph. This speed equates to a fast walk. It is reasonable to suggest the majority of people spend most of their time wheeling at speeds at which rolling resistance has the biggest influence on the amount of energy they have to expend to move.

In order to reduce rolling resistance, it is necessary to understand the contributing factors and how to minimize their impact.

Rolling resistance is the combined drag created by tires, wheels, and bearings. It is relatively constant whatever the speed of the wheelchair. When force is applied at the push rim it has to be transmitted from the push rim - to the rim - to the tire - to the ground, this will move the wheels on the ground. To move the wheelchair; the force has to pass from the ground - to the tire - to the rim - through the spokes - to the hub and then via the bearing and axle - to the axle sleeve - to the

chair. Any unwanted movement at any of these interfaces will result in increased rolling resistance. At most of these interfaces less movement will result in least rolling resistance, ideally the only movement that occurs should be within the bearing.

Tire / ground interface



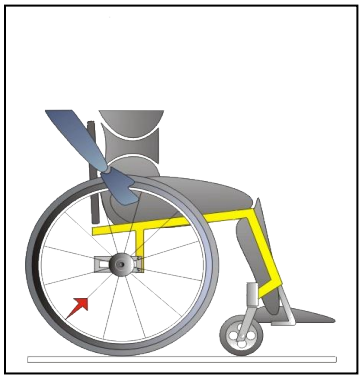
Deformation of the tire and road surface at the contact point produces heat; energy is lost (and rolling resistance occurs.) For example, a hard tire on a hard surface will produce hardly any deformation at all resulting in low rolling resistance. A soft tire on a hard surface will flatten as more weight passes through it. The increased contact patch between the tire and the ground increases rolling resistance. A hard tire on soft ground won't deform but the ground will deform significantly, thereby increasing the rolling resistance. A soft tire on soft/uneven ground will flatten and spread the weight of the chair and wheeler over a large surface area and produces minimal permanent deformation of the ground and a relatively low rolling resistance. Wide treaded tires perform best on soft and/or rough terrain e.g. grass, snow, sand and gravel etc.

If the material of the tire springs back elastically after the weight has been removed it is said to have low hysteresis, and the springing back action tends to keep the wheel rolling. A system with high hysteresis produces lots of friction and increase rolling resistance. Pneumatic tires have low hysteresis, especially high-pressure tires. Solid and semi pneumatic tires have high hysteresis and high rolling resistance.

Toeing error or scrubbing occurs when the wheels are out of alignment. As the wheel rotates and a segment of the wheel contacts the floor there should be no movement of the segment relative to the floor. (Imagine seeing a tire track in mud, the tread is easy to make out because no scrubbing occurred.) If the wheels was locked at the time you would see a skid mark with no discernable tread pattern. When a chair has toeing error the tire skids sideways a little as it rotates and this produces friction, which produces heat and the energy to produce the heat had to come from somewhere. A 1-degree toeing error increases rolling resistance by 50 %, 2-degrees increases it by 150%.

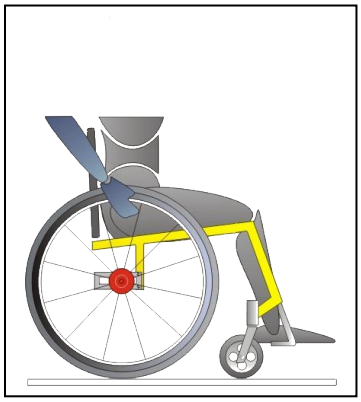
A wheel that is not round and true will increase rolling resistance.

Tire / rim interface



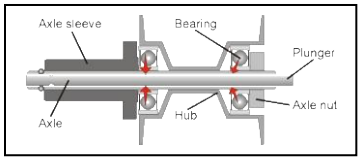
Any movement here will produce heat and reduce rolling resistance. The more intimate the fit between tire and rim, the less movement will occur. High quality solid tires need to be installed using a special tool that stretches the material. However, even when the solid tires are glued into place they can not compete with even the most basic pneumatic tires which are held in place with a pressure of 50lbs per square inch.

Rim / spoke / hub interface



Any movement between and within these structures wastes energy and increases rolling resistance. Plastic wheels tend to flex and they weigh more than a tuned spoked wheel and are therefore less efficient at transferring forces. Loose and broken spokes are bad news and should be dealt with as soon as possible. Spokes have to be able to withstand tension compression and side loading.

Hub / bearing / axle / sleeve interface



These components should all fit together snuggly with as little play as possible. The only movement should occur within the bearing itself.

Casters

Larger wheels have less rolling resistance than an equivalent small wheel this is due to a number of factors including the angle at which the wheel impacts small obstacles and the fly wheel effect of a larger diameter wheel. The resistance that a wheel contributes to the wheelchair's total rolling resistance is proportional to the total weight on that wheel. Therefore most of the weight should be placed over the wheels with the best rolling characteristics. Which in practically every case is the rear wheel on a manual chair.

So, in effect the more weight over the large rear wheels the less impact the caster will have on rolling resistance and the more freedom you have to choose a caster wheel and fork for its other characteristics. If the wheelchair pulls to one side when it is free wheeling there must be an asymmetry causing one side to have more rolling resistance than the other all you have to do is compare sides and figure out where the problem lies.

Test

First confirm that the chair actually does pull one way and it isn't asymmetry of wheeler strength or an uneven surface.

Choose a relatively flat regular surface:

1. Have the wheeler sit passively in the chair with hands off the wheels
2. Give one push to propel the chair as straight as you can for as great a distance as is available and note the distance rolled and the deviation. (Or let the chair roll down a small ramp)
3. Then do the same thing in the opposite direction to cancel out the effect of an uneven surface.
4. Repeat until you are satisfied that there is a deviation and how significant it is.

Repeat with an empty chair to see if the wheeler or his weight distribution contributes to the deviation.

Possible causes

Something rubbing

Listen and look at the chair as it rolls from front and back. Clothing, side guards, seatbelts, armrests, wheel locks, back packs, cushions all have the potential to rub on the wheel. Sometimes the wheelers foot can interfere with the free rotation of the caster.

Tire pressure

Make sure that pressure is equal on both sides, you need to use a gauge to do this since even with 50% of the recommended pressure the tire feels hard. If casters are pneumatic check them too.

Bearings

Lift one side of the chair rotate the wheel and feel for grinding and excessive side to side play, then spin the wheel to make sure it spins freely. If there is grinding the bearing needs replacing, if there is excessive side to side play the axle nut needs to be tightened. If the wheel doesn't spin

freely the axle nut needs to be loosened. The stem bearings should also be checked by lifting the front end and rotating the casters through 360 degrees, the bearing should allow smooth rotation of the caster stem.

Mechanical Error

Most chairs offer significant adjustability and it is possible to unintentionally do something to the right side of the chair that is different to the left side of the chair. A visual inspection with the aid of a tape measure will allow you to confirm that:

- Both casters and wheels match each other.
- Caster axles are in the same hole in the forks.
- Forks are the same length.
- Caster stems are the same length.
- Casters are mounted the same distance from the rear wheel as each other.
- Rear axles are mounted on the frame in the same place relative to each other. On chairs with camber plates you can count the indexing slots, with camber bars you have to measure the distance of the clamp securing the bar to the frame from a fixed part of the frame.
- Footrest tube on rigid chair is not jammed up one side further than the other side.

Adjustment Error

- Caster stems not vertical - use an inclinometer or other device to check for vertical from the front and from the side.
- Wheels not pointing in the same direction as the chair – measure from the tire to the frame in front of the axle and from the tire to the back cane behind the axle, the measurements front and back don't have to be the same but side to side they should.
- Camber – make sure that both wheels have the same amount of camber.

Damage

Occasionally wheelchair frames and their components are subject to forces, which cause them to bend and not return to their original shape:

Warped wheels

Spin the wheels and view from above or in front to check if the wheels are warped. Also check for warped wheels while they are loaded; have the wheeler wheel towards you and away form you looking at each wheel in turn. Remember that casters are wheels too and should be checked in the same way.

Damaged forks

Have the wheeler lean forward to put more weight through the casters. View the caster forks and wheels from the front to see if there is any movement or distortion that can account for the tracking error.

Damaged frame

With the wheeler sitting up, check the connections between all frame members at the back of the chair, check for cracks in the welds. Do the same with the wheeler leaning forwards, this time looking at the front end of the chair. As the wheeler moves his weight forwards and back look for movement or listen for creaking that might indicate a problem.

The wheelers weight may mask a bent frame. To eliminate this have the wheeler get out of the chair, put the chair on a flat surface and make sure that all wheels are in contact. If the wheels don't all touch, remove the casters to confirm it is the frame that is warped.

If you are unable to find the cause of the poor tracking after following this process return your chair to the dealer and wish them luck!

Appendix BB The template for intervention description and replication

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Item Number	Item	Primary paper (page or appendix number)	Other (details)
1	**BRIEF NAME** The wheelchair maintenance training program	Chapter 4 of this thesis	
2	**WHY** To measure the feasibility of wheelchair maintenance training program	Chapter 4 of this thesis	
3	**WHAT** **Materials**: Computer, laptop or tablet with access to the internet. Online platform to upload the questions	Chapter 4 of this thesis	
4	**Procedures:** Details are available in the Chapter 4 of this thesis	Chapter 4 of this thesis	
5	**WHO PROVIDED** For researchers and clinicians	Chapter 4 of this thesis	
6	**HOW** Intervention performed face to face	Chapter 4 of this thesis	

7	**WHERE** Rehabilitation research center	Chapter 4 of this thesis	
8	**WHEN AND HOW MUCH** Each participant came for two visits and completed the test during each visit	Chapter 4 of this thesis	
9	**TAILORING** N/A		
10	**MODIFICATIONS** N/A		
11	**HOW WELL** **Planned**: N/A		
12	**Actual:** Participants were able to complete all the scheduled sessions for this study.	Chapter 4 of this thesis	