Chairstairs: An Assistive Technology Device For Independent Wheelchair-To-Ground Transfers

Abilee Kellett and Justin Turner, Master of Occupational Therapy students
University of British Columbia

1) Problem Statement/Research Question and Background

Transferring between surfaces is an important part of wheelchair users' lives and are performed an average of 11 to 20 times each day (Koontz, Bass, & Cooper, 2015). When people think of wheelchair transfers, often what comes to mind are transfers to or from another surface that is similar in height, such as wheelchair-to-bed or wheelchair-to-car transfers. Transfers that are considered less often - by both researchers and builders of assistive technology (AT) - are those between wheelchair and ground.

There are many reasons why a wheelchair user may wish to transfer between chair and ground, for example to play on the floor with their children, enjoy a picnic in the park, practice yoga, service their wheelchair, or recover from a fall. There are many benefits wheelchair users experience when engaging in their desired occupations, such as deeper social connectedness, increased relaxation, decreased stress, and pressure relief (Chan & Chan, 2007; Ginis et al., 2003). Conversely, occupational deprivation in people who use wheelchairs has been linked with social isolation and increased prevalences of psychopathologies like major depressive disorder (Kalpakjian, Bombardier, Schomer, Brown, & Johnson, 2009; Rudman, Hebert, & Reid, 2005; Smith, Sakakibara, & Miller, 2016). Unfortunately, **independent and safe wheelchair-to-ground transfers are not easy or possible for every wheelchair user, creating a barrier that may lead to these negative consequences**.

Presently, transferring between the ground and a wheelchair is most commonly accomplished with external aids, such as getting help from another person, using a mechanical lift, or first transferring to a surface of intermediary height between a user's wheelchair and the ground, for example a couch (Kondo, 2015). Another option practiced by some wheelchair users are direct transfers from the wheelchair to the floor, but this requires sufficient upper extremity strength and range of motion (ROM), and places high biomechanical demands on the users' upper limbs (Alappat, 2015; Koontz et al., 2015). Challenges faced when transferring between surfaces of various heights are described by Toro, Koontz, & Cooper (2013); not only are these transfers difficult for some individuals, but very few wheelchair users are able to successfully complete transfers that require an elevation change of greater than six inches. Since the seat to floor height of wheelchairs generally ranges from 13 to 20 inches (Future Mobility, 2014), many wheelchair users are not physically able to safely or successfully complete direct transfers independently. The question is, **can independent and safe wheelchair to ground transfers be facilitated using assistive technology?**

To address this problem, we have created ChairStairs, an AT device that enables wheelchair users to independently access the ground. Our hope is that this device will be able to provide increased independence and access to meaningful occupations, which in turn will lead to improved mental, physical, and psychosocial well-being.

2) Methods/Approach/Solutions Considered

Currently, there are few AT devices on the market designed specifically to facilitate transfers between wheelchair and ground - the Bottoms Up Bar being the only one we were able to find (AbleData, n.d.) - and none that can be attached and stored directly on the wheelchair when not in use, which creates a barrier to full participation for those wishing to engage in activities on floor-level surfaces. The second author of this proposal, Justin, first considered this barrier while experiencing Guillain-Barre Syndrome, necessitating the use of a wheelchair for mobility over four months due to neuromotor paralysis of muscles controlling voluntary movement of his lower extremities. During this time, Justin would visit his preschool-aged cousins, and faced the challenge of engaging with them in play activities on the floor, as he lacked sufficient upper body strength to independently transfer directly from his wheelchair to the ground. Justin later discussed this problem with the first author of this proposal, and together we considered different solutions using AT.

The first solution we explored was to develop a small slide-type device, which would attach to the front of the wheelchair and allow the individual to slide from the wheelchair to the ground. The main problems we identified with this design are (1) it would be difficult to ascend, i.e. get back from the ground to the wheelchair, and (2) its use may create shearing forces that could lead to skin breakdown.

Our second idea was to create stairs that could attach to the front of the wheelchair. Stairs, we thought, could overcome the challenges of a slide design because they could be ascended more easily and would allow for more controlled movements that would reduce the risk of skin damage. We discussed this idea with colleagues in occupational therapy, physiotherapy, and engineering, as well as people who use wheelchairs in their day-to-day life - all of whom encouraged us to pursue its development. After consideration of several stair designs, we decided upon an adaptation of scissor steps, which are described in the following section.

3) Description of Final Approach and Design

The final design we adopted is an adaptation of scissor steps, which are commonly used on recreational vehicles (White, 2010). We decided upon this idea after consulting with Kerith Perreur-Lloyd, engineering technologist and co-founder of the mobility device company SideStix

Ventures Inc. (SideStix, n.d.). The benefits of scissor steps are that they easily adapt in height, can be made with lightweight and durable materials, and can be readily deployed and stored in a small configuration under the wheelchair when not in use. Scissor steps operate via a scissors mechanism known as a pantograph; each step is connected on each end to the next step by parallel mechanical linkages that can extend and compress.

ChairStairs are secured to the underside of the wheelchair seat-pan via a steel bar atop the structural frame of the wheelchair*. To access the ground, the user deploys the stairs by pulling on and releasing a velcroed strap, then leaning forward and manually guiding the stairs forward and down to the ground. The rubber non-slip feet ensure a quiet, non-scratching, and secure non-slip contact with the floor. Once contact between ChairStairs and the ground has been established, the user shifts forward in the wheelchair seat and transitions down the steps one by one, starting from the wheelchair, then to the top of one step, next to the top of the following step, and, finally, to the ground. There are a total of two steps in our design, with an adjustable rise of 6 inches, a run of 6 inches, and a width (parallel to front of wheelchair seat-pan) that can range from 12 to 20 inches*. ChairStairs have an estimated weight of 6lbs but the final design will vary depending on wheelchair size and individual needs. Reductions in weight will require future outcomes testing to ensure structural integrity is maintained.

*Note, the ChairStairs prototype was designed to fit the wheelchair that was available to us. Attachment configuration will vary depending on the wheelchair make and model. Various customization options are possible without compromising the device's or the wheelchair's structural integrity.

4) Outcome (Results of any outcomes testing and/or user feedback)

At this time, we have yet to complete outcomes testing and acquire user feedback. This is a research area that we consider fundamental to the development of ChairStairs, and plan to pursue this avenue of evidence-based data collection in the future.

Limitations we foresee include the following: users would likely require good postural control, sufficient upper body strength to ascend and descend the ChairStairs, the ability to safely weight-bear through the wrists, and adequate ROM at hip flexors for forward bending to deploy and retract ChairStairs; these limitations restrict the number of people who could benefit from the product. Nonetheless, a large number of wheelchair users do meet the biomechanical criteria to use ChairStairs (Koontz et al., 2012), hence many people could benefit from their use.

5) Cost (Cost to produce and expected pricing)

There are presently no comparable AT devices on the market to facilitate transfers between wheelchair and ground that attach directly to the user's wheelchair. The following table provides a cost breakdown of the materials used to create the ChairStairs prototype.

Item	Cost	Total
¼"-20 x ¾" hex bolts	26 x $0.10	$2.60
¼"-20 nyloc nuts	26 x $0.40	$10.40
Aluminium bars	20 x $2	$40
Aluminium steps	2 x $20	$40
Strap for securing (incl. rivet and velcro)	1 x $8	$8
Rubber non-slip feet (incl. rivet)	2 x $1	$2
	Total	$103

Total costs including labour costs and modifications will depend on method of production, for example customization, mass production, or partnerships with specific wheelchair manufacturers.

6) Significance

Having an AT device attached directly to a user's wheelchair enables an individual to complete transfers between wheelchair and ground safely and independently whenever and wherever they choose to do so. The ergonomic aspects of the design may minimize risk of injury. The compact and lightweight aspects allow the device to be permanently attached to the wheelchair if desired, with little added weight - meaning ChairStairs are transportable after installation. This universal access can increase autonomy by decreasing reliance on environmental factors and external aids.

The potential impacts of such an AT device are both short- and long-term; ChairStairs may enable wheelchair users to engage in meaningful occupations that are otherwise challenging to access, which may lead to reduced occupational deprivation and longer-term benefits that may improve an individual's overall well-being and quality of life.

An exhaustive search revealed only a small number of AT devices to assist in wheelchair-to-ground transfers. Other than the previously mentioned and commercially available Bottoms Up Bar, there have been at least two other devices submitted in previous years to the RESNA Student Design Competition: the "Lift Me Up" Device (Gupta, Haac, Khan, Rao, Goldberg, & Caves, 2010) and the "Little Helper Step" (Hatfield, Leonard, James, & Castro, 2014) - the latter of which was a semi-finalist. With the addition of ChairStairs as a student design submission, it is our hope that an increased number of AT researchers and designers will consider the wheelchair-to-ground transfer as an avenue of further exploration.

7) Acknowledgements

ChairStairs was conceptualized during an AT module taught by Bill Miller and Emma Smith. We would therefore like to thank our instructors for assigning such an imaginative assignment that provided us with the foundation and motivation to develop our design and for encouraging us to pursue our idea. To the creators and co-founders of SideStix Ventures Inc., Sarah Doherty and Kerith Perreur-Lloyd, who coincidentally happen to be one of the sets of one of our parents. Thank you for granting us access and free reign to your workshop and tools, without which our idea may have remained a simple conceptual solution. Thank you especially to Kerith Perreur-Lloyd for coaching us through the development process and methodology of creating a working prototype, and for volunteering a very generous number of hours as a consulting engineer. To Russ Kellett (Abilee’s dad), and Jerry Schneider: without you we would not have had a wheelchair or the materials to work with that were vital to the construction process. To the individuals who were consulted for the ChairStairs AT assignment. Thank you for believing in the value of our design in a bigger context. Because of your support and feedback, ChairStairs has the potential to provide individuals with increased independence and safe access to meaningful occupations.

References

AbleData. (n.d.). *Bottoms up bar*. Retrieved from http://www.abledata.com/product/bottoms-bar

Alappat, M. (2015). *Floor to wheelchair transfer.* Retrieved from http://www.spinalcordessentials.ca/PDF/SCE2-Ma4-Floor-To-Chair-Transfer.pdf

Chan, S. C., & Chan, A. P. (2007). User satisfaction, community participation and quality of life among Chinese wheelchair users with spinal cord injury: a preliminary study. *Occupational Therapy International*, *14*(3), 123-143.

Future Mobility. (2014). *Future Mobility Healthcare wheelchair chart*. Retrieved from http://www.futuremobility.ca/files/eng_Chairchart.pdf

Ginis, K. A. M., Latimer, A. E., McKechnie, K., Ditor, D. S., McCartney, N., Hicks, A. L., ... & Craven, B. C. (2003). Using exercise to enhance subjective well-being among people with spinal cord injury: The mediating influences of stress and pain. *Rehabilitation Psychology*, *48*(3), 157-164.

Gupta, A., Haac, J., Khan, N., Rao, V., Goldberg, R., & Caves, K. (2010). *"Lift me up" device*. Retrieved from http://aac-rerc.psu.edu/wordpressmu/RESNA-SDC/2010/05/19/lift-me-up-device-university-of-north-carolina-at-chapel-hill/

Hatfield, L., Leonard, M. L., James, W., & Castro, B. (2014). *A fighting bid: The little helper step.* Retrieved from http://rehabdesign.web.unc.edu/?projects=a-fighting-bid-the-little-helper-step

Kalpakjian, C. Z., Bombardier, C. H., Schomer, K., Brown, P. A., & Johnson, K. L. (2009). Measuring depression in persons with spinal cord injury: a systematic review. *Journal of Spinal Cord Medicine*, *32*(1), 6-24.

Kondo, E. (2015). *3 Floor to wheelchair transfers*. Retrieved from http://www.ablethrive.com/life-skills/3-floor-wheelchair-transfers

Koontz, A., Bass, R. S., & Cooper, R. A. (2015). Independent wheelchair transfers in the built environment: How transfer setup impacts performance. Phase two: Final report. VA Human Engineering Research Laboratory. Presented to the United States Access Board November 2015. Retrieved from http://herl.pitt.edu/ab/ABTransferSetupReportPhaseII.pdf

Rudman, D. L., Hebert, D., & Reid, D. (2006). Living in a restricted occupational world: the occupational experiences of stroke survivors who are wheelchair users and their caregivers. *Canadian Journal of Occupational Therapy*, *73*(3), 141-152.

SideStix Ventures Inc. (n.d.). *Founders*. Retrieved from http://www.sidestix.com/founders/

Smith, E. M., Sakakibara, B. M., & Miller, W. C. (2016). A review of factors influencing participation in social and community activities for wheelchair users. *Disability and Rehabilitation: Assistive Technology*, *11*(5), 361-374.

Toro, M. L., Koontz, A. M., & Cooper, R. A. (2013). The impact of transfer setup on the performance of independent wheelchair transfers. *Human Factors, 55*(3), 567-580.

White, G. (2010, May 3). Torklift International GlowSteps. *Truck Camper Magazine*. Retrieved from http://www.truckcampermagazine.com/news/torklift-international-glowsteps/