Further Development of a Robotic-Assisted Transfer Device

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Background: The task of performing transfers, such as from a wheelchair to a bed, has a high risk of injury to both the caregiver and the person being transferred. Although mechanical transfer devices can reduce these risks, these devices are not meant for use in the community and they still place strain on the caregiver when used. **Purpose:** The aim of this study is to describe feedback gathered from focus groups of potential users of the Robotic-Assisted Transfer Device (RATD) and describe design changes aimed at preparing the device for the next step in the development process. **Method:** The RATD was transferred to a newer electric-powered wheelchair (EPW), key components were redesigned, and the control program was updated to increase the safety of the device. Two focus groups, one consisting of people with disabilities and the other consisting of clinicians and caregivers, were conducted to gather feedback from potential users. **Results:** Error checking, safety zones, a motor brake, and a new track helped increase the safety of the device. Sixty-three percent of the people with disabilities and 83% of caregivers surveyed said they would use the device. **Conclusions:** The results from the focus groups were positive and the design changes were successful, but more development is needed before the RATD can be marketed. **Key words:** assistive technology, disability, wheelchair

As of 2010, the US Census Bureau reported that 18.7% of Americans had a disability and 12.6% had a severe disability; 3.6% of people with disabilities use a wheelchair.¹ With the population of people with disabilities increasing, it is estimated that there will be 16.1 million caregivers in the United States by 2020.²

Research has shown that over time, repetitive strain from independent transfers can lead to the need for caregiver-assisted transfers.³ During caregiver-assisted transfers, there is a high risk of injury to both people with disabilities and caregivers.³ Back pain was the most common injury reported among nurses,⁴ and the majority of back pain experienced by nurses was from transferring patients.^{5,6} Although lifting devices lower the forces exerted on the lower back during transfers,⁴ studies have found 72.8 N to 3,500 N of force are placed on L5.^{5,7} Transfer tasks such as moving a person from a bed to a wheelchair are rated the most physically challenging tasks that caregivers perform.⁸

Government initiatives promote the hiring of people with disabilities, so there is increasing need for devices that allow for their community integration.⁹ Many people with disabilities face

environmental barriers that limit community integration.¹⁰ Technology to assist in transfers is one of the most important tools used to promote independence and community integration.^{11,12}

Current Transfer Devices

Current transfer devices, such as the Hoyer Advance (Hoyer) and HoverJack (Hovertech International), help reduce the forces on the lower back that cause injury.^{7,13} Use of these transfer devices is less physically demanding for caregivers and more comfortable for people with disabilities.⁶ However, these devices have shortcomings, such as not being transportable, having limited use in crowded living spaces, and taking longer to use than manual lifting.⁵⁻⁷ These devices also shift the location of the injuries to the shoulder and upper arm.¹⁴

Initial Design

The Robotic Assisted Transfer Device (RATD) has 5 degrees of freedom that allow it to rotate, elevate, extend, fold up, and move to the back of the electric-powered wheelchair (EPW) when not in use (**Figure 1**). The initial version was attached

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Top Spinal Cord Inj Rehabil 2017;23(2):140–146
© 2017 Thomas Land Publishers, Inc.
www.thomasland.com

doi: 10.1310/sci2302-140

Figure 1. Robotic-Assisted Transfer Device.

to a Permobil C500 EPW for easier transport and is rated for transferring a person weighing 220 kg.¹⁵ The caregiver controls the RATD by applying force to an instrumented handle, which only requires a maximum force of 20 N in any direction due to an algorithm that takes in the readings from the instrumented handle and actuates one joint at a time.¹⁶ Wang et al developed equations to determine the stability of the system and to keep the EPW from tipping due to the weight placed on the RATD.¹⁷

Methods

Focus groups

To provide guidance for the next iteration of the prototype, 2 focus groups were conducted. Twenty wheelchair users were recruited to participate in a focus group at the National Disabled Veterans Winter Sports Clinic (WSC). Seven caregivers and clinicians with at least 1 year of transfer experience participated in a separate focus group at the Human Engineering Research Laboratories (HERL), Pittsburgh, Pennsylvania. Both focus groups had Institutional Review Board approval and were conducted in the same manner, with small differences in the questionnaires based on population (people with disabilities or caregivers).

After obtaining informed consent and before a short presentation on the features of the RATD, a short survey was given to the participants. This survey collected basic demographic information such as age, gender, and race, type of disability, years of transfer experience, assistance needed or performed, types of assistive technology used, and attitudes about technology. Another survey was given after the presentation. This survey asked participants their general opinions of the RATD, such as usefulness, safety, reliability, and attractiveness, and included additional questions about current transfer methods and locations. A short discussion followed the completion of the surveys, which was aimed at providing researchers with more qualitative feedback. A moderator led the discussion, asking the participants questions such as, “What were your overall impressions of the device?”, “Where do you see the device being most useful?”, and “Are you scared of robots?”

The data were analyzed using IBM SPSS Statistics. To simplify the analysis, the questions that used 7-point Likert scales were condensed. When a question asked a rank of importance, 1 to 2 was considered *not important*, 3 to 5 was *neutral*, and 6 to 7 was *important*. This same method was used for questions that asked for a level of agreement with a statement: 1 to 2 was considered *disagree*, 3 to 5 was *neutral*, and 6 to 7 was *agree*.

Design adjustments

To prepare for subject testing, mechanical and software changes were implemented. The RATD was moved to a Permobil F5 EPW. Because of design differences between the previous EPW and the F5 EPW, a new attachment mechanism was needed.

Instead of attaching the track directly to the seat, a mounting plate was designed to attach the track to the base of the wheelchair; this increased stability of the system. The plate (**Figure 2C**) was fabricated from steel and is almost hidden underneath the seat of the EPW. A new track had to be designed

Figure 2. (A) Old track design. (B) New track design. (C) Mounting plate for F5 wheelchair.

to strengthen the attachment points between the track segments (**Figures 2A and B**) The final mechanical change to the RATD was the addition of a brake on the shoulder joint motor to prevent any unintended movement.

There were 3 major changes to the software program that controls the RATD. First, the weight reading needed for the safety zones was changed from a continuous reading to a one-time reading. This made the program more efficient and reduced the chances of software errors. Second, safety zones were implemented. Although the equations that governed the safety zones were derived,¹⁷ they were never calculated and put in the program. Last, error checking was implemented using a simple if/then statement to check for unusual spikes in the sensor values being read via the instrumented handle.

Results

Focus group: People with disabilities

The focus group at the WSC consisted of 14 men and 6 women. The average time of wheelchair use was 16 years (± 11), and the average number of years after onset of disability was 20 years (± 14). Twelve participants were manual wheelchair users, 6 used an EPW, and 2 used a combination of manual wheelchair, EPW, and scooter. When asked about technology, all participants were either neutral or agreed that “Technology makes life

easy and convenient” and “I like the idea of using technology to reduce my dependence on other people.”

The results of the post-presentation survey of the overall opinions of the RATD are shown in **Table 1**. Only 37% of the participants said they would not use the RATD and only 26% said that the RATD would not make their lives easier. All participants agreed that the development of the RATD was important and 84% agreed that the government should invest resources to further develop the RATD. Participants rated reliability, durability, and stability as most important aspects of the device, whereas appearance was least important.

During the discussion, the people with disabilities were most concerned about the size of the device. They reported that for the most part they would be unable to use it in public bathrooms because of size constraints. They thought the device would be good for travel, but stressed that the device would have to be protected to prevent damage. The people with disabilities also wanted to be able to operate it independently. When asked about the new design, they liked the idea of outriggers and passive degrees of freedom (DOF), but thought there should be options.

Focus group: Caregivers

The caregiver focus group consisted of 4 men and 3 women. The average age was 43 years (± 14). One caregiver helped a person who used both a manual

Table 1. Results of the post-presentation survey of people with disabilities on their opinions of the Robotic-Assisted Transfer Device (RATD) ($N = 20$)

Survey statements	Disagree <i>n</i> (%)	Neutral <i>n</i> (%)	Agree <i>n</i> (%)
I would choose to use the RATD.	7 (37)	4 (21)	8 (42)
Using the RATD would make my life easier.	5 (26)	6 (32)	8 (42)
Learning to use the RATD would be easy for me.	4 (21)	7 (37)	8 (42)
I would be anxious (nervous) about using the RATD.	7 (37)	9 (47)	3 (16)
It would be embarrassing to be seen using the RATD.	7 (37)	8 (42)	4 (21)
The government should invest resources to develop the RATD.	0 (0)	3 (16)	16 (84)
It would be easier to just get another person to help rather than use the RATD.	11 (58)	4 (21)	4 (21)
It's important that we develop technology that can do this.	0 (0)	4 (22)	14 (78)

Note: Totals may not represent full cohort due to blank responses.

Table 2. Results of the post-presentation survey of caregivers on their opinions of the Robotic-Assisted Transfer Device (RATD) ($N = 7$)

Survey statements	Disagree	Neutral	Agree
I would choose to use the RATD.	1 (14)	4 (57)	2 (29)
Using the RATD would make my life easier.	0 (0)	5 (71)	2 (20)
Learning to use the RATD would be easy for me.	0 (0)	2 (33)	4 (67)
I would be anxious (nervous) about using the RATD.	2 (29)	5 (71)	0 (0)
It would be embarrassing to be seen using the RATD.	3 (50)	3 (50)	0 (0)
The government should invest resources to develop the RATD.	0 (0)	3 (43)	4 (57)
It would be easier to just get another person to help rather than use the RATD.	3 (43)	3 (43)	1 (14)
It's important that we develop technology that can do this.	1 (14)	1 (14)	5 (71)

Note: Totals may not represent full cohort due to blank responses.

wheelchair and a power wheelchair, and 6 caregivers said their clients exclusively used power wheelchairs. All caregivers had used transfer devices: 2 caregivers used hydraulic lifts, 3 caregivers used powered lifts, and 3 caregivers used ceiling lifts. In terms of experience, 42.9% of the caregivers had less than 5 years of experience performing transfers. Three caregivers reported being injured during a transfer.

Only 14% of the caregivers said they would not use the RATD and all of them either thought it would make their lives easier or were not sure if it would make a difference. Five out of the 7 participants said that the development of the RATD was important and 57% agreed that the government should help fund the development (**Table 2**). When asked to rate the importance of aspects of the RATD, the caregivers said that reliability, stability, and safety were most important and visibility was least important.

During the discussion, the caregivers focused on how safe the device would be. They saw potential problems with the current design such as lack of a display, the ability to move the chair during the transfer either on purpose or by accident, and a limited range. They also expressed concern that the extra weight of the arm on the chair would negatively affect the functions that the chair was designed for. For example, a few caregivers worried that the extra weight of the arm would put too much torque on the seat elevator and damage it. When asked about the new design features, the caregivers were uncertain that they would add enough benefit. Instead they stressed the availability of options, such as fully powered DOF versus partially powered DOF or outriggers versus no outriggers.

Design changes

Using the new attachment plate, the RATD was successfully moved to the Permobil F5 EPW. The addition of the brake on the shoulder joint motor reduced the risk of unintended movement. The new track pieces reduced the strain on the connection points by rounding the edges and removing the taper.

In the software control program, the safety zones now limit the rotation of the shoulder joint (from horizontal across the EPW seat outward) to 155° for weights less than 50 kg, 70° for 50 to 75 kg, 45° for 75 to 100 kg, and 30° for 100 kg and above. The one-time weight reading done at the beginning of the program increased the efficiency of the program so that it now only takes 50 ms to cycle through. The error checking successfully pauses the program if it detects any abnormalities in the readings from the instrumented handle.

Discussion

The participants' responses to the post-presentation survey were promising. A majority of the people with disabilities were either neutral or agreed that they would use the RATD. This is especially promising considering that this focus group consisted mainly of people who use manual wheelchairs, which is not the target market. The group was most concerned with the size of the device limiting the places that the device could be used. Independent operation of the device was also important to focus group members, perhaps

because most of them were manual wheelchair users. They also were very much in agreement that the government should fund further development of the device

The caregivers responded more neutrally to the device. They had more safety concerns, but expressed willingness to try the device if they thought it was safe. Some of the caregivers did not think the government should fund further development of the device, but offered no alternative funding source.

The caregivers and the people with disabilities had similar opinions about what was and was not important when it came to aspects of the RATD. The only aspect they disagreed on was removal from the EPW. The caregivers did not think that this was important and the people with disabilities did. Both groups stressed that the device should have multiple options such as powered versus nonpowered DOF, lighter versions based on the weight of the PWD, and outriggers as an add-on.

Even though the safety zone limit stops the rotation to increase safety, it restricts the range of motion of the arm; this could limit its usefulness by certain people. This drawback could be addressed in future design changes.

Most of the time focus groups are conducted to inform design changes, but the focus group and the design changes discussed here were performed independently of each other. The design changes prepared the device for usability testing. After the usability testing is complete, the results from the

focus groups discussed here and the results from usability testing will be combined to inform a revised design.

Conclusion

The results from the focus groups are positive, but more work is needed before this device is usable by those who could benefit from this technology. The device needs to be lighter weight and more durable, stable, reliable, and user friendly. To reduce weight, some of the DOF such as the folding and storing of the device could be changed from powered to passive. The 6-axis load cell used for testing could be replaced by a smaller single-axis load cell that reads the weight of the person. In addition to the safety zones that help keep the system stable, an outrigger or extra counterweight could be added to increase stability.

There were some limitations to this study, such as small sample size and convenience sampling. Because of this, the focus groups were not representative of the target population.

Future work on the RATD will include testing during which caregivers use the device to transfer a mannequin, a redesign of the RATD based on the results from the focus groups, and the subject testing of the RATD.

Acknowledgments

The authors report no conflicts of interest.

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