Survey assessing assistive technologies and activities of daily living

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INTRODUCTION

Studies show that individuals with quadriplegic spinal cord injuries (SCI) rank restoring grasping capability as their highest priority [1,2]. Patients with a C5-C7 incomplete SCI lose their abilities to grasp and hold, but wrist flexion/extension functionality is almost universally retained [3]. Conventional rehabilitation techniques take advantage of this retained wrist function through the tenodesis effect: wrist extension for grasping and wrist flexion for releasing [3]. Current tenodesis wrist-hand orthoses (WHOs) engage just the thumb and index finger, resulting in only 20% of activities of daily living (ADLs) that can be completed [3]. A previous study looked at the design and development of a student-designed wrist hand orthosis (WHO) to help individuals with an incomplete C6-C7 SCI re-gain grasping capabilities (Figure 1). This prototyped WHO utilizes a modified [reverse] tenodesis grasp (wrist flexion for grasping and wrist extension for releasing) to operate in
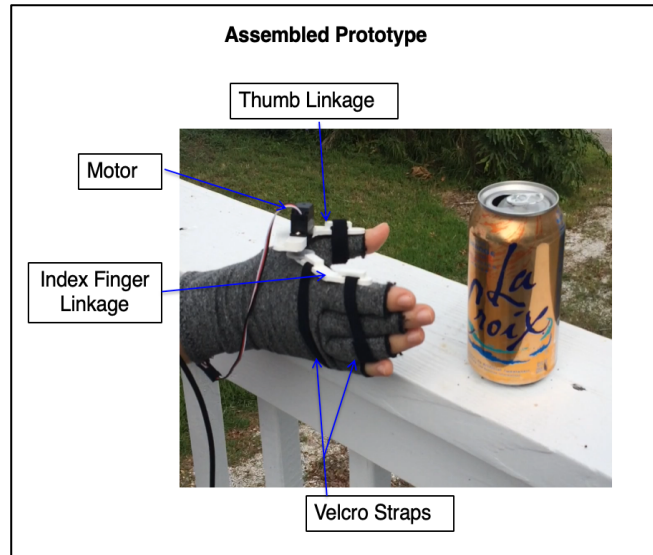

Figure 1: Student-Designed WHO

a more intuitive manner and allows for whole-hand gripping and completion of more ADLs [4,5,6]. Before the device is tested on the target population, there is a need to gather information on whether this SCI population would benefit from an assistive device to help with grasping ADLs. A survey was created and distributed to individuals with a spinal cord injury to gather information on: (1) difficulties (if any) when grasping objects, (2) ADLs that can and cannot be completed independently, and (3) whether or not any upper limb orthoses had been tried in the past.

METHODS

The *Assistive Technologies Survey* was created on SurveyMonkey and distributed (via email) to the sample SCI population, as well as to clinicians that aid individuals with SCI. The survey included questions related to:
- Level (severity) of spinal cord injury,
- Amount (degrees) of wrist flexion and extension,
- Ability and/or inability to grasp objects,
- Abilities and/or inabilities to independently complete activities of daily living (brushing teeth, eating, drinking, etc.).

RESULTS

Level and type of spinal cord injury

Thirty-five individuals responded to the survey; thirty-three identified as having some classification of SCI, one was a clinician, and one had cerebral palsy (CP). Approximately 33% of the SCI responders (11/33 responses) have a C6-C7 SCI with the original target population (those having an incomplete C6-C7 SCI)
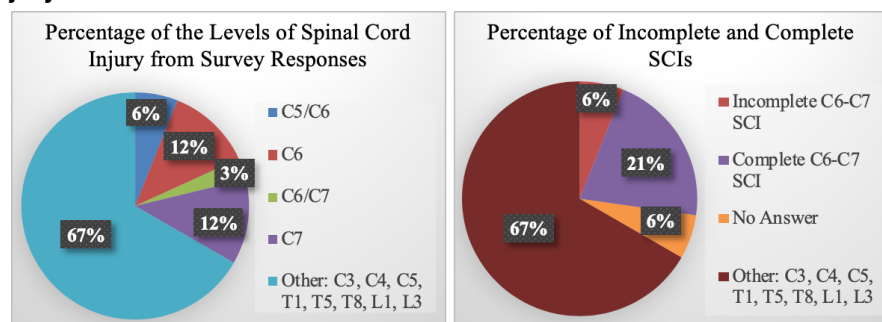

Figure 2: Assistive Technology Survey Results: Percentages of the levels of SCI and whether the injury is complete or incomplete

represented by at least 6% (2/33 responses), or at most 12% (4/33 responses), (see Figure 2). Note that two responding individuals did not answer whether their SCI was complete or incomplete, hence the 6% minimum/12% maximum levels stated. Based on the previously cited studies [1,2], it was originally hypothesized that only those individuals with an incomplete C6-C7 SCI would have retained wrist motion and would benefit from this device. However, based on survey responses, individuals with **both** an incomplete **and** a complete C6-C7 SCI retain some degree of wrist motion and would be able to use the prototyped orthosis. If the two undeclared responses are complete SCIs then, based on the original hypothesis, this WHO would have helped just 6% of the population, however, this device can actually benefit 33% of the SCI population, roughly six times the original supposition. If, on the other hand, the two undeclared responses are actually incomplete SCIs then the percentage of potential users rises from 12% of the population to 33% of the population, almost three times as many individuals. Regardless of the actual classification of the two undeclared respondents, the key takeaway is that the target population has drastically increased to roughly 33% of the SCI population, which is several orders of magnitude greater than originally hypothesized.

Wrist flexion/extension limitations

As stated earlier, the original hypothesis was that this WHO could help only those individuals who have an incomplete C6-C7 SCI, as they would retain wrist motion, which is the basic requirement for the device's operation. However, the survey results clearly indicate that individuals who have a complete C6-C7 SCI still retain some wrist motion. Specifically, all seven individuals who responded as having a complete SCI also responded that they retained wrist motion (Table 1).

Table 1: Respondents with a complete or incomplete SCI retain wrist motion

Level of Injury	Incomplete or Complete	Wrist Motion	Wrist Flexion Ranges	Wrist Extension Ranges
C5/C6	Complete	Yes	11°-20°	21°-30°
C6	Complete	Yes	61°-70°	61°-70°
C6	Complete	Yes	61°-70°	61°-70°
C6	Complete	Yes	31°-40°	31°-40°
C7	Complete	Yes	51°-60°	51°-60°
C7	Complete	Yes	41°-50°	41°-50°
C7	Complete	Yes	61°-70°	61°-70°
C6/C7	Incomplete	Yes	11°-20°	11°-20°
C7	Incomplete	Yes	41°-50°	41°-50°
C5/C6	Unspecified	Yes	0°-10°	61°-70°
C6	Unspecified	Yes	41°-50°	41°-50°

It is worth noting that one individual who responded as having a complete C6 SCI did comment that he/she had tendon transfer surgery which increased his/her tenodesis grasp (wrist extension) capability. This particular response clearly indicates that this individual had some wrist flexion/extension ability prior to the tendon transfer surgery, with the surgery resulting in increased wrist extension. To reiterate the main point, 100% of respondents that self-identify as having C6-C7 SCI retained some wrist motion and all are candidates for using the orthosis to independently complete ADLs. The breakdown of the wrist flexion/extension ranges for responders is shown above in Table 1.

For individuals with a complete C6-C7 SCI Table 1 shows there was one response (14%) for each wrist flexion range 11°-20°, 31°-40°, 41°-50°, 51°-60° and three responses (43%) for the wrist flexion range 61°-70°. Similarly, there was one response (14%) for each wrist extension range 21°-30°, 31°-40°, 41°-50°, 51°-60° and three responses (43%) for wrist extension range 61°-70°. For individuals with an incomplete C6-C7 SCI, responses for wrist flexion and extension ranges were the same: 11°-20° and 41°-50°, with each range receiving one response (50%). As mentioned earlier, there were two individuals who did not specify whether they had an incomplete or

complete SCI, however, they did respond positively regarding retained wrist motion. One individual had 41°-50° of both wrist extension and wrist flexion, while the other individual had 0°-10° of wrist flexion and 61°-70° of wrist extension. Individuals with asymmetric flexion/extension ranges would be candidates for special programming of the orthosis control system in which the wrist motion input is dis-proportionate to the finger motion output. For example, the orthosis can be programed to output 5° of finger motion for every 1° of wrist motion input. If a user is limited to 10° of wrist extension input, the device can be programmed to open the finger linkages 50° rather than just 10°.

Level of difficulty grasping and method of grasping

The top of Figure 3 shows the difficulty survey responders have in grasping everyday objects. Among the target population responses (11 individuals), the most common response, with 50%, was "some difficulty". Objects in a vertical orientation (labeled with V on the figure) are the easiest for responders to grasp; 55% have difficulty grasping or cannot grasp a toothbrush, 63% have difficulty grasping or cannot grasp a utensil and hairbrush, and 73% have difficulty grasping or cannot grasp a razor. Survey responses indicated the full ceramic mug is the most difficult to grasp; 45% responded they cannot grasp a full ceramic mug.

The bottom of Figure 3 shows the method survey responders use to grasp everyday objects. For all twelve objects, one handed grasping is the most common method, with it being used 61% of the time. The full ceramic mug, full plastic bottle, and empty ceramic mug are objects that require respondents to grasp using both hands; 82% require both hands to grasp the full ceramic mug and full plastic bottle, and 55% grasp the full plastic bottle using both hands.
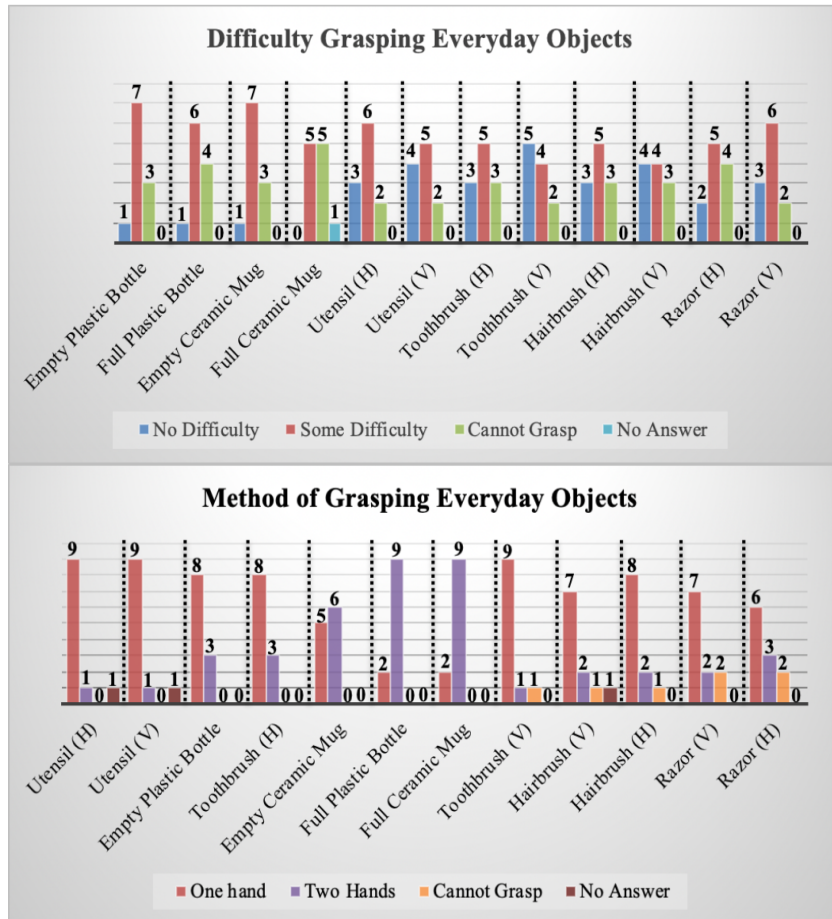

Figure 3: Top: difficulty in grasping everyday objects, Bottom: method of grasping everyday objects

Previous orthosis use and likes/dislikes

Table 2 below shows that about 27% (3 individuals) of responders within the target population have used an orthosis. Only one individual provided the specific type of orthosis, but all three liked that their device allowed them either to independently complete ADLs or that the device could be independently donned/doffed, or both. Individuals disliked their orthosis for not being customizable, not being aesthetically pleasing, and/or being too larger (bulky) and heavy, i.e. not being "user friendly".

Table 2: Survey responses indicating prior orthosis use and the likes and dislikes

Level of Injury	Incomplete or Complete Injury	Have you used an Orthosis?	Orthosis Likes	Orthosis Dislikes
C6	Complete	No		
C6	Complete	No		
C6/C7	Incomplete	No		
C7	Complete	No		

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C7	Complete	No		
C7	Incomplete	No		
C6		No		
C5/C6		No		
C5/C6	Complete	Yes	Ability to don/doff	Not Customizable
C6	Complete	Yes	Independently complete ADLs	Aesthetics; Not Customizable
C7	Complete	Yes, tenodesis splint	Independently complete ADLs; Independent don/doff	Size; Weight

CONCLUSION

The *Assistive Technology Survey* was distributed to a small SCI population. Results showed that the prototyped WHO can help a much broader range of SCI patients than was originally hypothesized. Approximately 33% of responders identified as having a C6-C7 SCI with 6%-12% having an incomplete C6-C7 SCI, and at least 21% having a complete C6-C7 SCI. The basic premise that only individuals with an incomplete C6-C7 SCI retain wrist motion is contradicted by real survey responses, indicating that individuals with **either** an incomplete **or** a complete C6-C7 SCI actually retain wrist motion and would benefit from use of this orthosis. The key takeaway is that the target population has increased considerably to more than 30% of the SCI population, several orders of magnitude greater than originally hypothesized.

Additionally, it can now be concluded that individuals with a C6-C7 SCI (complete or incomplete) retain wrist motion, although in many cases, it is a limited range of motion. Regardless of the amount or range of wrist flexion/extension, the device can be effectively used. The operational code can be individually customized such that the wrist motion input is dis-proportionate to the WHO linkage (finger) motion output.

Further, information from the *Assistive Technology Survey* shows that objects in a vertical orientation are easiest for responders to grasp. This is in-line with hypotheses proposed prior to ADL testing of the orthosis. The full ceramic mug, full plastic bottle, and empty ceramic mug were the objects that required the majority of respondents to use both hands to grasp. This is most likely attributable to the heavy weight of these objects coupled with respondents thinking that "grasp" meant "grasp, pick up, and use" the object the relatively underpowered WHO motor not created a secure, firm grasp.

Results from this survey will help improve the design of this orthosis. The first modification will be to install a motor that can maintain a tight grip on objects, especially those that are considered heavy. Additionally, for the next study, each subjects' limited wrist ranges of motion should be measured, so, if necessary, the device programming can be modified and customized (input is disproportionate to the output) for the specific individual.

REFERENCES

[1]. National Spinal Cord Injury Statistical Center (2016).

[2]. Sukhvinder Kalsi-Ryan; 2012 The graded redefined assessment of strength sensibility and prehension: reliability and validity. *Journal of neurotrauma*.

[3]. Rune Thorsen; 2013 A noninvasive neuroprosthesis augments hand grasp force in individuals with cervical spinal cord injury: The functional and therapeutic effects. *The Scientific World Journal*.

[4]. Gatto, Amber; 2019 The Design and Development of a Wrist Hand Orthosis. RESNA 2019 Annual Conference, Emerging Technologies.

[5]. Gatto, Amber; 2018 The Design and Development of a Wrist Hand Orthosis. University of South Florida's Graduate Research Symposium

[6]. Gatto, Amber; 2018 The Design and Development of a Wrist Hand Orthosis. National Academy of Inventors Student Innovation Showcase.