Post Stroke Balance Augmentation Device to Incentives Return to Active Hobbies During Recovery

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Augmenting Human Dexterity – Spring 2022
Term Project: Report and Research Proposal

Abstract

Every year more than 795,000 adults in the US experience a stroke. This is followed by both physical health deterioration (of about 7.9 percent) and mental impact (4.1 to 72 percent). While physical impacts limits the impacted individual's ability to carry out daily activities, the physical limitations severely affect one's ability to return to activities they once enjoyed, thus having a toll on their mental well being. Physical rehabilitation continues to be the best option in aiding the return to normality, however the impact on the mental state often impedes rehabilitation therapies, prolonging treatment, often leading to muscular atrophy and inability to return to one's original physical form in terms of strength and abilities. In an interview with a stroke survivor, the potential of an intervention, that would aid in returning of the individual to daily activities, specially those that they particularly enjoyed, was highlighted as a means to address both, aiding in mental health and physical well being of the individual. Using interview insights, we hypothesize that an upper body exoskeleton with a very brief learning curve could address issues of both physical limitations and social and mental well being of the user. A functional prototype of such an exoskeleton was developed, incorporating sturdy arms to replace the need for balancing oneself for activities that required bending, such as gardening and pottery, while allowing sufficient flexibility when performing these tasks. To determine if one's ability to perform such tasks would improve, a self-reported evaluative study was proposed where stroke survivors would be asked to perform simple talks in a controlled environment where their balance was tested both with and without the exoskeleton. All necessary precautions were proposed, keeping in mind the well-being of the study population. On comparison, if the hypothesis holds true and the exoskeleton's support proves to be a natural balance and support provision without any discomfort, this work could motivate further development of upper body support devices that incorporate technical simplicity and account for natural body movement. It is proposed to test if such a device might be used in supplement to rehabilitation processes as it would make the latter more enjoyable. Such devices could potentially then be adopted by populations at large for support to survivors of other medical conditions that also affect strength and balance.

I. Introduction

800,000 Americans suffer a stroke every year [1]. After a stroke, the patient is likely to suffer from Paralysis (inability to move some parts of the body), weakness, on both or one side of the body. Trouble with thinking, awareness, attention, learning, judgment, and memory and depression are all common conditions after a stroke [2]. One of the common rehabilitation methods that clinicians use is to encourage the patient to take part in activities that enrich their daily life, and by doing so, activate joints, strengthen muscles, improve hand- eye coordination and regain a sense of independence [3]. In recent years, robotic assistive technology, such as exoskeleton robotic devices, has gained popularity in stroke rehabilitation for upper limbs. These devices allow repetitive motion and training without the direct involvement of a therapist. However, most current innovations in upper limb assistive devices have had difficulty gaining traction for a few different reasons. Specifically, patients hesitancy toward technology, applicability in practice and usability [4]. Additionally few devices on the market assist in daily activities and focus exclusively on rehabilitation exercises [1]. This report explores the possibility of an assistive device that is targeted to assist in activities that are preformed crouching or kneeling on the ground (e.g. gardening, pottery, etc.). We propose that a device that supports the trunk encourages the patient to take part in activities that enrich their daily life, as mentioned above, and therefore improve both mental and physical aspects of post stroke conditions. We see a gap between exoskeleton rehabilitation devices providing the ability to preform repetitive training movements and an assistive device that helps the user to perform daily tasks and activities with user interest. By having an exoskeleton device that is simple to use and supports the user when preforming tasks that are of interest to him, we believe we can address that gap.

A. Background

Stroke: The term stroke refers to any damage to the brain due to abnormality in blood supply, it usually refers to abrupt damage. The two main causes of stroke are lack of blood flow to the parts of the brain- ischemic stroke. And hemorrhage, that causes bleeding into the brain and skull which cuts off parts of the brain from blood supply and causes pressure that can damage the brain [5]. Stroke survivors, are left with physical and mental disabilities and impairments. Some of these include: lack of balance, muscle weakness, visual problems and depth perception. And mental condition as depression hesitancy and memory problems. This is a condition where the patient has a time window of 3-6 months of improvement. After 3 months, most patients will still have trouble with reaching age normal gait speed levels and upper extremity strength. 37% still need assistance with activities of daily living. After one year, 67% still report lower than expected physical and mental health. Most patients struggle mainly with endurance [6].

Stroke Rehabilitation: The first part of the rehabilitation involves classification of the stroke, disabilities, impairments and health of the patient. This can be done with WHO's international Classification of Functioning, Disability and Health frame work. A key factor in a successful rehabilitation process in all types rehabilitation is physical activity, a notable mental and physical deterioration occurs as a result of lack of activity [7]. From observing stroke rehabilitation results we can see that a patient with high motivation is more likely to see better rehabilitation outcomes. A Main part of rehabilitation is aimed for neuro-rehabilitation which is the process of recovering the nervous system to recover or minimize damage cause by the stroke. Commonly used principles are task and context specific training. For example, repetitive walking on a treadmill while receiving feedback from a therapist is a common rehabilitation method. Studies show that rehabilitation should preferably happen in the patients own environment or context [8].

Upper Limb Stroke Rehabilitation: Common practices, that will be reviewed here, for upper limbs rehabilitation after stroke are the Constraint-Induced Movement Therapy (CIMT) and Robotic Assisted Therapy. CIMT therpy has three major components: Constraining the non affected arm, Repetitive motion and Task Specific Training. Patients will wear some form of mitt or restrictive artifact on the non affeted arm and preform a task for 15- 20 minutes a day while receiving feedback from the therapist [9]. Robotic assisted rehabilitation is the use of any robotic device (e.g. exoskeleton, motorized gloved or any electromechanical device used for stroke rehabilitation). Studies show that patients who receive this type of therapy are not more likely to see improvement in activities of daily life and might see improvement in strength of affected arm. [10].

B. Overview

We hypothesize that an assistive device that supports upper body weight and balance in crouching or kneeling body posture, results in an increase participation of areas of interests in post-stroke patients who previously took part in that activity frequently. As discussed in Section I-A, upper limb rehabilitation requires training by repetitive motion while receiving feedback from a therapist. Studies show that task specific rehabilitation that happens in the patients own environment are more effective. While recent advancements in robotic assisted rehabilitation allow for more training with reduced attention from therapists, these methods do not account for the users personal tasks of interest like hobbies, personal goals and emotional stress from intense rehabilitation. An interview with an individual 6 months after ischemic stroke in Section II emphasised that lack of balance and strength remained a large deterrent to access the activities they enjoy, like gardening and pottery. The interview illuminated the need for a device that could blend into the user's daily routine without need of additional learning that comes from using a highly specialised technological invention. To address this need we present in Section III an assistive device (Seen in Fig. 1 below) that is a mechanical exoskeleton that assists in activities that require the user to crouch or kneel, thus allowing the user to do gardening, pottery or other activities in this posture that are not possible to a post stroke patient suffering from loss of balance, hesitancy, loss of confidence, vision spatial issues and muscle weakness. If this hypothesis holds true, this study could have numerous impacts on studies and the development of assistive devices customized to user needs and personal goals as discussed in Section IV. As argued in Section V, these findings could have a much broader impact on the impact of assistive technology in stroke rehabilitation. By tailoring the rehabilitation process and technology used to patients own interests, the technology used can provide a more wholesome solution.

Fig. 1: The Proposed Assistive Exoskeleton Device

II. Preliminary results

To ensure the device would address key pain-points we interviewed an eighty year old stroke survivor. Our generative research consisted of interviewing our need knower at their place of residence, allowing us to conduct a contextual inquiry, and an ethnographic study that gave us insight into understanding the interviewee's experiences and perspectives when in their own living environment. We observed them perform their daily tasks, taking field notes during this time, and followed up with a formal 90 minute interview. Each of these helped us make informed design decisions and also made of aware of physiological and behavioural attributes of the interviewee. During the interview, the interviewee spoke about how instrumental rehabilitation had been in helping them gaining back normalcy in their daily life. They noted extravagant technological interventions had done little to improve their experience had had often proved to too difficult to adopt. They repeatedly emphasised that the lack of balance and strength had remained, even after rehabilitation and it remained a large deterrent to access the activities they enjoys, like gardening and pottery. The interview illuminated the need for a device that could blend into the user's daily routine, without need of additional learning that comes from using a highly specialised technological invention. It also underlined how the lack of balance and strength in the user led to a significant decrease in their ability to participate in social activities they enjoyed and how this had lead to isolation in many ways for the user. They also felt limited in carrying out any tasks that required physical exertion such as cooking meals, beekeeping, pottery, some of which directly affected the users' work. livelihood and social and mental well-being. Although rehabilitation brought back their strength to return to daily activities, further development was now slower and the interviewee had resigned from these completely, in fear of injuries or social implications. Finally, their insurance provider had prescribed a generic device that had actually had negative impact on their ability to regain motor skills. One such had cut into their foot and caused serious infections, forcing them to seek out alternatives them self. The lack of personalised care made the user hesitant to try out new devices. Additionally, most new devices involved a steep learning curve. Overall, the interview gave us an incredible amount of insight and the full list of needs touched upon in in Appendix A, however an abbreviated list, relevant to the hypothesis may be found in Table I. We concluded that the assistive device would require simplicity in design and would have to assist with the physical limitations in stroke patients that limit day to day activities requiring balance and upper body strength.

TABLE I: Key Customer Needs

Customer Statements	Customer Need
" I enjoy keeping bees and gardening but it's hard to garden without falling."	The AT enables activities that require bending or carried out while sitting and prevents falling while doing ADL.
"... he had the same experience that I had, which is that the rehab hospital gave him what I had, they gave me one that was made out of hard plastic. And I cut into the sole of my foot, and I developed blisters, which of course, got infected. And then I had another additional problem to deal with. The AT is customized to allow good fit to the user."	The AT should have a soft connection to the skin. The AT prevents rubbing on the skin while using.
"The other thing that is gone is my balance. Pottery helps with my balance, improves hand eye coordination and I know how to re-start since I have done it since i was 9 The AT improves training for hand-eye coordination."	The AT assists with balance training. The AT can help in a way that looks natural.
" feel like I'm in overload a lot of the time, so I'm learning one more thing. "	The AT is intuitive and does not require learning.
" ..I can't hold and throw that amount of clay (40 pounds) and twist it and make anything but my hands aren't strong.. enough and my small muscles don't work that well to mold anything that well..."	The AT is a multi-tool for a specific group of tasks. The AT compensates for loss of strength.

III. Methods

A. Device Concept:

To allow a patient to take part in hobbies that require crouching or kneeling, we have developed an exoskeleton device that supports the user's weight while crouching by transferring the upper body load to a metal frame attached to the user. By doing so, the user does not have to support his own weight and he is free to work in the mentioned position without the fear of losing balance or getting tired.

B. Device Description:

The exoskeleton Fig.2 is made out of an aluminum frame that straps on to the users back by the shoulders and waist. The frame has a metal link on both lateral sides that is free to rotate in the sagittal plane (see Fig 5a. To allow the user to move laterally while crouching, as the shoulder joints do, the connection of the links to the frame is done with a ball joint. This additional degree of freedom (DoF) is designed to improve balance by allowing some lateral movement but also limiting it, preventing the user from tilting and falling when shifting their weight laterally (see blue arrow Fig 2 and Fig 5b).This DoF is limited by the Hex Nut securing the Ball Joint to the Frame. The distal part of the link has a plate that is designed to increase stability by allowing more surface area in contact with the ground. This plate is to support the weight of the torso, as the human hand does. The connection between the plate and the link has an additional degree of freedom of rotation in a parasagittal plane, performed with a clevis rod end. This connection takes the part of the human wrist and is designed to allow the distal plate to be normal to the ground at different ground inclinations. The distal plate and the clevis rod end are connected to the link through a spring to help the user get up from a crouching position. In Fig. 3 a demonstration of the use of the device is shown. For BOM see Fig. 11 in Appendix C.

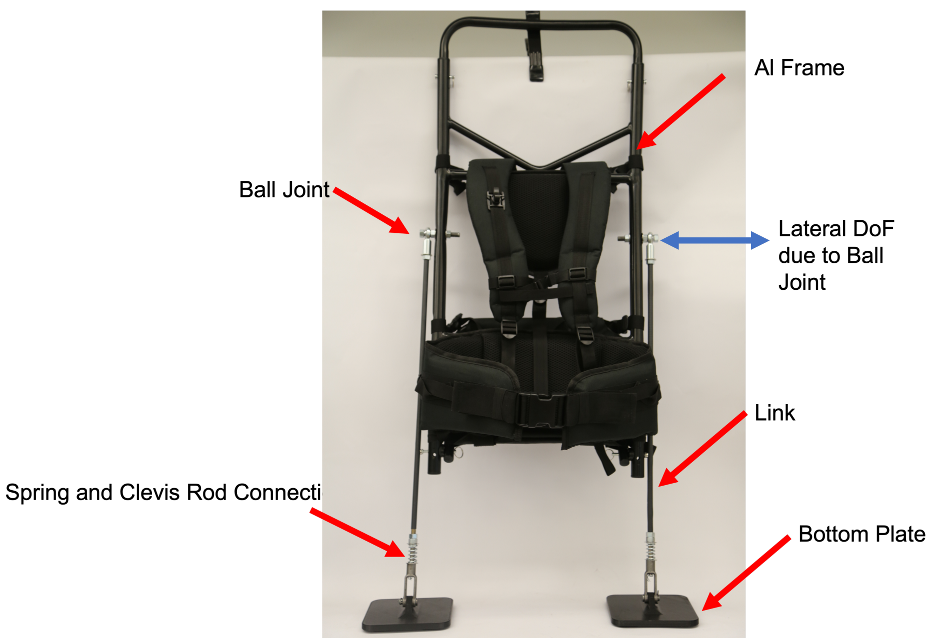


Fig. 2: Front View of Device

C. Proposed Study:

The study will be done in two phases.

- **Phase one** will include usability testing and safety tests.
  - **Usability Testing** will test weight reduction from shoulders and wrists achieved by using the device. Additional testing will check the stability of the device. We will attach force sensors to

(a) Kneeling Position with Left Hand Supporting Upper Body

(b) Similar Position with AD Supporting Upper Body

Fig. 3: Device Demonstration

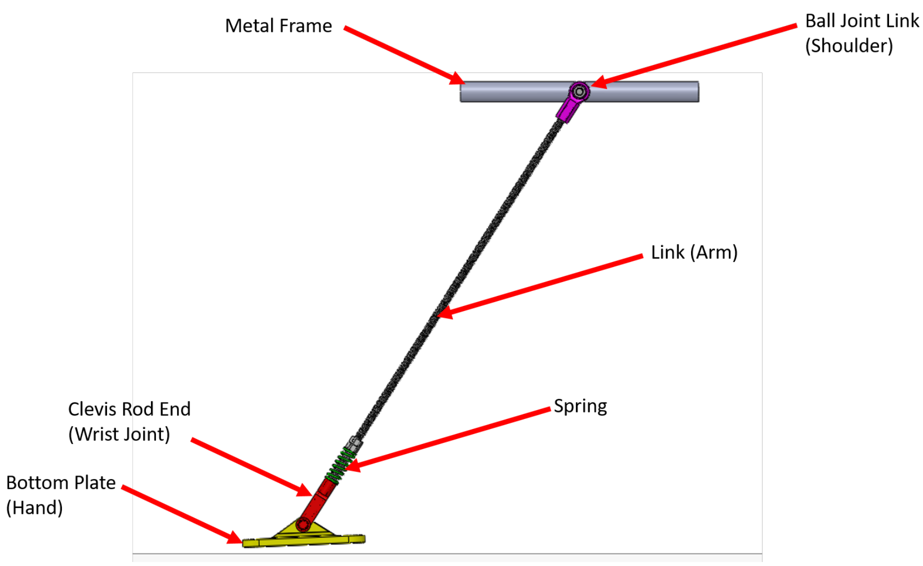


Fig. 4: 3D CAD Model with description of each main component and the equivalent human body part.

the spring and measure the weight that the device is transferring to the frame. For this test and the safety test, we will define 3 positions of the body by torso to hip angle and by arms to torso angle. We will also define positions by the part of the lower limbs in contact with the ground. This will allow us to have a reference point to compare the device performance compared to maintaining the same body posture without the device. The usability testing will help us better define the optimized link length based on users physical parameters.

  - **Safety Testing** will measure failure angles of the device to compare to maximum range of motion achieved without the use of the device and by supporting the upper body with the arms. Additional safety tests will include maximum and minimum weight and height the device can support and ground surface types that are safe to use.

- **Phase Two** will be testing the device with 20 subjects.
  - **Acceptance Trials** will include 20 voluntary subjects will be selected, introduced to the device and interviewed every 4 weeks for 3 months. The subjects should have the following characteristics:
    1) stroke patients with more than 6 months after suffered a stroke.
    2) The subjects should have an interest in gardening or other activities that require crouching

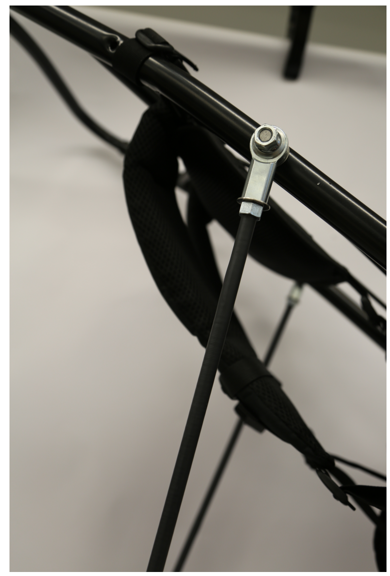
or kneeling.

3) The subjects should be able to crouch or kneel.
4) The subject should suffer from muscle weakness and balance.
5) The subject should be mentally capable to take part in clinical trials.

The interviews will check the subjects average use time of the device, perception of the device, fear of falling and general condition using the ABILHAND questionnaire [11].

We have completed the CITI training Group 1: Biomedical Research Investigators as of April 2022. We intend to receive IRP approval prior to starting any subject trials.

(a) Side View of Device



(b) Ball Joint- Side View

Fig. 5: Side View of Device and Ball Joint Connection

	(1) Strongly Agree	(2) Disagree	(3) Neutral	(4) Strongly Agree	(5) Not Applicable
1. I felt myself losing balance without the exoskeleton					
2. The exoskeleton made bending down to do the task(s) easier					
3. The exoskeleton supported my upper body weight & my arms were free for work					
4. The exoskeleton allowed for natural movement when in use					
5. I could successfully carry out the task(s) without losing my balance					
6. I would use the exoskeleton when carrying out tasks that require bending or working on the ground					
7. I would use the exoskeleton in social settings if activities required it					

Fig. 6: Questionnaire for Qualitative Measure of Success of Exoskeleton

1. Did you prefer to carry out tasks today with or without the exoskeleton?
   a. Could you explain your answer above?
2. Did the exoskeleton provide support to your upper body weight so that your hands could be free if requires?
3. Did the exoskeleton provide support to your balance when bending or sitting while performing the task(s)?
4. Did the exoskeleton allow for natural flexibility when it came to shifting your weight and back and forth movement when performing the task(s)?
5. Would you consider using the exoskeleton in social settings with close friends and family?
6. Would you consider using the exoskeleton in social settings with with accquaintances or strangers?
7. On a scale of 1-10 how much support did you feel from the exoskeleton when it came to balance and weight support?
8. Please describe any kind of discomfort you might have felt using the device?

Fig. 7: Questionnaire for Free Response to Success of Exoskeleton

IV. Intellectual Merit

Through this proposed study and AD developed, we can demonstrate the impact of supporting the strength and balance needed for activities that require kneeling down on the ground for stroke patients as they recover these physical abilities themselves through rehabilitation. This is a novel device, the first of it's kind when compared to other devices used post stroke for users' to increase their daily activities and provides a new perspective and platform with which to study the potential role of assistive devices to support well being post-stroke. While there's plenty of room for development when it comes to this particular AD design, the study validates the use of an exoskeleton to demonstrate assisting balance and support of upper body weight in this space. It is proposed further research may validate if the device itself can promote movement and strength building in users recovering from stroke through enjoyable activities and can be used in supplement to rehabilitation. It's also proposed to research further into minimising the size of the device and improve the design for addressing a wider range of situations than this study looks into to be applicable for a larger audience with different activity needs. We also recognise the need for addressing the conspicuousness of the device to address social comfort. Addressing these concerns can promote further commercialised development and distribution of such an assistive device for stroke patients. This study would also benefit from further user testing to verify if it truly addresses the needs and if it can truly be incorporated in the daily life of stroke patients and if it may be used as a supplement to rehabilitation therapy and strength training by small and incremental modifications of the device. With exoskeletons specifically, there's the concern of weight and size that interfaces differently for different individuals. Research into these metrics would be extremely beneficial for the exoskeleton engineering and academia.

V. Broader Impact

This study demonstrates the potential assistive medical devices could have in rehabilitation and support for stroke patients as they return to normal daily activities and has the potential of significantly impacting development in this field. By having the assistive device addressing both physical and mental aspects of rehabilitation, it could change the way current assistive devices are designed to suit more individual user's interests and goals to provide a more wholesome treatment. It could also be used for patients affected by a large number of medical conditions besides stroke, that mitigate one's ability to sustain balance and strength. Device customisation is easily possible and allows for each user to access this technology based on their specific needs. A larger adoption of such an assistive device would also take away any social stigma around using an exoskeleton to carry about daily tasks and aid in users' ability to carry out tasks independently, thereby affecting their mental health and directly address their quality of life. It also shortens the amount of time the latter need to bring back activities they enjoyed pre-stroke and return to their life as they knew it. This in turn might promote quicker development in physical and mental strength when compared to solely relying on regular rehabilitation procedures. The simplicity of the design also favours its potential of being adopted into the maker community and potential of individual modifications and keeping it open source implies that it may be freely replicated to suit individual requirements in size and strength of support. In fact, the detail engineering components and design has been included in the appendix and the team urges users to access these resources to create their own Stratera Exo device. Finally, large scale adoption may be key to adoption of these devices across the medical field, urging for de-stigmatisation of the use of exoskeletons and expedite research in the latter space.

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Appendix A
Investigational Device Details

A. *Collecting and analyzing interview data*

Customer Statement	Interpreted Need
”The first round of activity when I got out of the hospital was handicapping my house complying with disability ordinances relating to construction.	The AT can replace handicap accessories in case of a space that is not equipped for handicaps. ”
”My bathroom are with grab bars, I changed a lot of things in places I could got into trouble.	The AT can grip or provide support when there’s a risk of falling. ”
”...hired a personal care nurse. She’s not a nurse. She’s like an LPN nurse’s assistant. She’s terrific, and her job was to help me Not fall, and helped me get used to using things in a way that would be safer for me just simply, you know, you know, to stand at the kitchen counter and chop an onion. But to do it in a way that wouldn’t, wouldn’t lead to some disastrous fall or something.”	The AT can grab tools and use them in a safe manner.
”I slept a lot more than I had anticipated, I’m tired now and I didn’t get active until 7. In the olden days at this time I was planning lunch for 4-10 ppl. I’m not doing that anymore.”	The AT reduces the energy used by the user in ADL.
”I got up, made myself coffee.. A protein shake with vitamins and I rowed for 10 minutes. I showered and made breakfast, made garden plans with Joe. We just harvested honey with the extractor.”	The AT allows gardening activities while with a cart.
”I frequently have guests for lunch and dinner. I have a young friend that does the shopping, I design the menu, and we cook together. I had a party for 15 people and she did the heavy lifting.”	The AT can help perform cooking tasks, to make large amounts of food for hosting.
”I enjoy keeping bees and gardening but it’s hard to garden without falling.”	The AT enables gardening while sitting. The AT prevents falling while doing ADL.
”I am recovering from a stroke, I’m very weak, I need to build my strength. ”	The AT is body powered to allow strength training. The AT provides strength training.
”I need a Personal trainer to crack the whip. To say we need another 14 reps…someone who understand the psychology and physiology ”	The AT pushes the user to train and use his strength.
”I feel like I’m in overload a lot of the time, so I’m learning one more thing. ”	The AT is intuitive and does not require learning.
”Well, I can’t, for example, work in the garden, is that something a lot? Oh, every single day, yeah. And it really hurts my heart that I can’t take care of my precious little plants. But I fall so I garden only when someone is with me and use my little cart.”	The AT provides an extension to allow gardening while sitting. The AT can perform gardening tasks.

”My brother is somewhat younger than I am. And he and his friend were the same age, early 70s, late 60s, early 70s. And Chris has had two strokes. And I’ve had several phone conversations with him. And it’s been very helpful. He was the one that put me on this brace. Yeah, he has one. And he had the same experience that I had, which is that the rehab hospital gave him what I had, they gave me one that was made out of hard plastic. And I cut into the sole of my foot, and I developed blisters, which of course, got infected. And then I had another additional problem to deal with. The AT is customized to allow good fit to the user. ”	The AT should have a soft connection to the skin. The AT prevents rubbing on the skin while using.
”...Also, he and I talked about, you know, your emotional bandwidth, which is severely limited. I mean, it’s just, it’s just, you know, you just don’t have the kind of resiliency you know, I’ll go into a whole total panic over not being able to find my purse or my phone. ”	The AT is easy to locate. The AT can be used without much fitting to hand.
”It’s so hard to tinker, hold tools and pottery. I just vacuum and check and leave. It’s a humiliating experience. I can’t hold and throw that amount of clay (40 pounds) and twist it and make anything but my hands aren’t strong enough and my small muscles don’t work that well to mold anything that well. Teacups right now but she’s getting there The AT enables the use of tools.”	The AT is a multi-tool for a specific group of tasks. The AT compensates for loss of strength. The AT makes griping easier- reducing the strength needed from hand muscles.
”The other thing that is gone is my balance. Pottery helps with my balance, improves hand eye coordination and I know how to re-start since I have done it since i was 9 The AT improves training for hand-eye coordination.”	The AT assists with balance training. The AT can help in a way that looks natural.
”No sensory rehabilitation, her heat sensation has been lost but she discovered it by chance. Thought “oh this is dangerous’ ’. Not assessed in the hospital. Was just told that she will lose sensory feelings on the left side.”	The AT should have temperature feedback for safety.
”...Isn’t very strong, so cant do volumes of food preparation like she once did. So I need help.”	The AT helps with repetitive ADL tasks in cooking.
”I am not eager to adapt to new tech, my plate is already full. No technology that can make me move any more gracefully than regular exercise. If any device can help me move with more balance and more graceful, I’d do it immediately ”	The AT can assist in a way that looks graceful.

”Nothing wrong with my brain. Chris suggested the walker and I use it to carry things around. Walker is super nifty and moves like skateboard wheels.”	The AT can perform task while with walker alongside

B. *Hierarchical list of primary and secondary customer needs*

Sub labels	Importance Rating
The AT replaces other handicap accessories	3
The AT provides support in case there's risk of falling	3
The AT helps grab tools safely	3
The AT provides temperature feedback for safety	1
The at prevents falling down while gardening	5
The AT is soft connected to the user	1
The AT prevents rubbing on the skin	5
AT is almost an extension to the arm	3
AT aids performance based tasks in combination with her walkers	1
AT enables user to use other tools	1
AT acts as a multitool for a specific task	1
AT allows gardening when on her cart	3
AT reduces strength needed for gripping using hand muscles.	1
AT helps perform lengthy tasks like cooking	3
AT helps perform repetitive ADL tasks (also like cooking)	3
Reduces energy used by the user	1
Allows strength training	3
Pushes user to use his own strength	3
Helps user with balance training	5
Compensate for lack of strength	1
Improves hand eye coordination	3
AT is intuitive to use i.e no training is required to use it.	5
AT can be easily mounted.	5
AT is easy to locate.	1
AT assists in a way that enables graceful movement	3
AT enables user to carry out previously enjoyed activities such as hosting guests and gardening	1

C. Brain Storming and Solution Generation

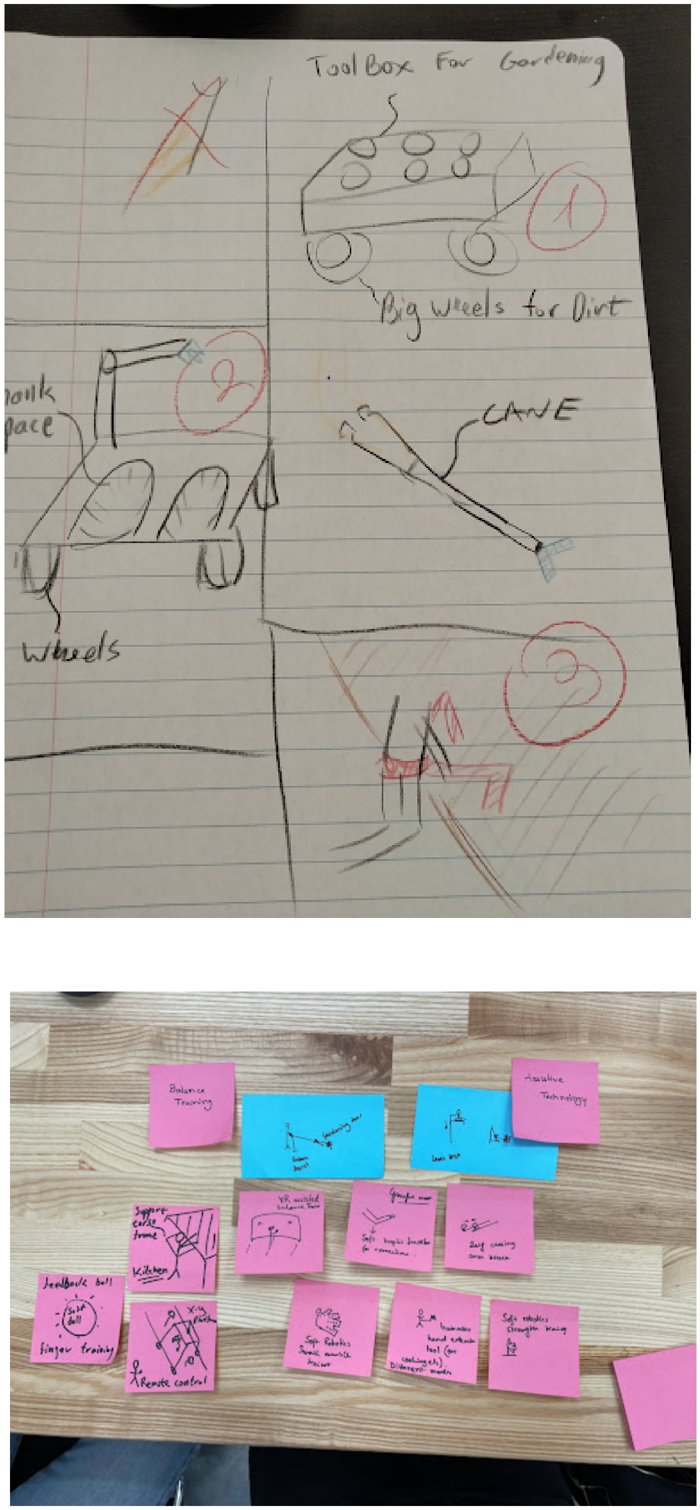

Fig. 8: Brainstorming

Themes of Brain Storming Session

- Exoskeleton to replace arms for balancing- Links that support body weight to replace arms. The device allows the user to use his arms for different tasks while he is on the ground working.
- Multi-tool Arm Extension- For tasks that require the user to crouch down on the ground (e.g. gardening), the multi-tool category serves as an extension with multiple task available at the end effector.
- Feedback rehabilitative training - a cluster of devices that serve as rehabilitation training devices. They all have feedback from different colors, lights or sound, that allow the user to keep progressing and helps him be consistent with training.
- VR/AR Training - a cluster of either robotics that works through an AR application or a pure VR training to perform rehabilitating tasks.

D. Converging on a single idea:

	Weights Jonathan	Weights Ramyani	Total Weights	Multitool Latching	Exo for crouching	Glove training	Wrist Mechanism	Fine motor training with light feedback
Prevents Falling	2	1.5	1.75	3	5	0	0	0
Rehab Training	0.5	2	1.25	1	2	5	0	5
Prevents rubbing	2	2	2	4	2	3	2	4
Intuitive to use	0.5	1	0.75	4	4	5	3	4
Easy to Mount	2.5	1.5	2	4	2.5	4	4	4
Graceful	2.5	2	2.25	3	2	3	3	3
Total Wight Points	0	0	**Total**	32.25	57	52	46	45

Final Idea

When a person with balance issues, as common in stroke patients, is doing a task crouching on the ground (e.g. gardening), and loses balance, they often find themselves balancing themselves with their arms. With compromised balance after stroke, as well as compromised arm strength, the patient often find it difficult to find balance while crouching when they cannot compensate for lack of balance with their arms. This assistive device allows the person to have an extra set of arms to help him balance. By helping the user balance, his arms are free to do any task without the fear of falling. A common symptom for stroke patients is the lack of activity due to the risk of falling. Having an assistive device for this will not only allow the person to be more active and therefore improve his rehabilitation, but also be more productive and active with his hobbies.

APPENDIX B
DESIGN PROCESS- CONCEPT 2

During the design process we developed two concepts for the device. In Fig 9 is presented the concept that was not chosen for production. The link has a profile that can better withstand bending in the sagittal plane. The mechanism (Fig 10) connecting the link to the Aluminum frame has 2 set positions for closed and opened mode. This model was not chosen because it does not allow side movement in the frontal plane and has less flexibility for different angles of the supporting link due to having only two set positions in the mechanism. Additionally the connection to the Aluminum frame through the clamp is last robust than the attachment method in the chosen concept.

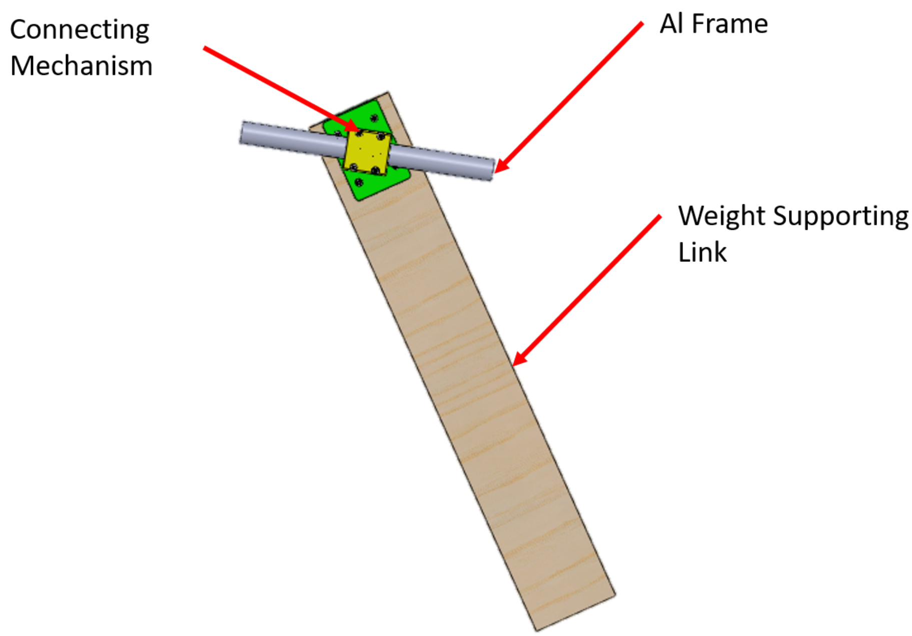

Fig. 9: 3D CAD Model with description of each main component of Concept 2.

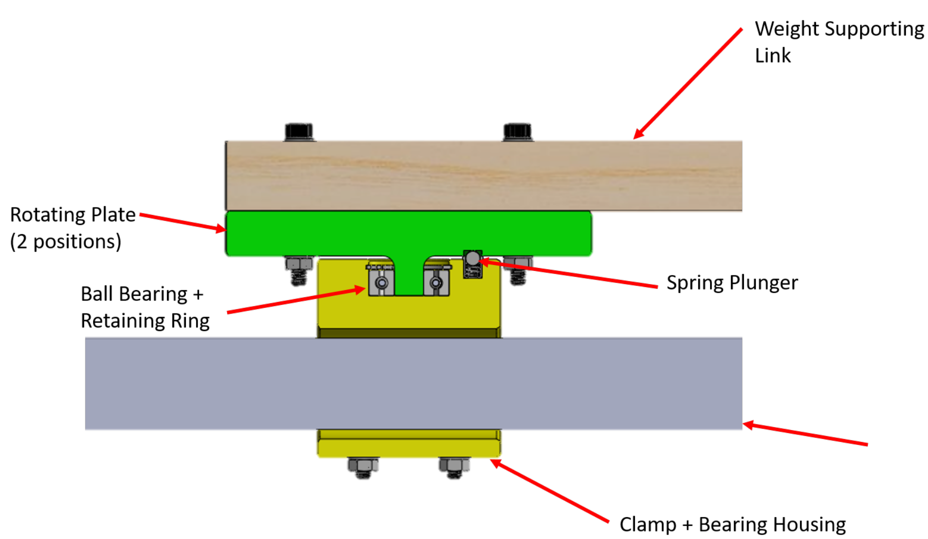

Fig. 10: 3D CAD Model with description of each main component of the mechanism design of Concept 2.

Appendix C
BOM

#	Part	Component	Supplier	Qty.	Note
1	Aluminum Frame	Stansport Deluxe Freighter Aluminum Pack Frame, One Size	Stansport	1	Can be any Backpack Frame with side rods.
2	Metal Links	Grade B7 Medium-Strength Steel Threaded Rod, 3/8"-24 Thread Size, 2-1/2 Feet Long	McMaster 98957A141	2	Length By User: For 5'4"-5' 7": 2.0-2.5 ft. For 5'7"-6'0": 2.5-3.0 ft. Drill 1/8" hole 5/16 of an inch from end of rod, for cotter pin.
3	Shoulder Joint (Ball Joint)	Ball Joint Rod End, 3/8"-24 Thread	McMaster 60645K34	2	
4	Rod connecting Ball Joint to Frame	Grade B7 Medium-Strength Steel Threaded Rod, 3/8"-24 Thread Size, 3" Long	McMaster 98750A463	2	
5	Hex Nut	Medium-Strength Steel Hex Nut, Grade 5, Zinc-Plated, 3/8"-24 Thread Size	McMaster 95462A515	12	
6	Washer	18-8 Stainless Steel Washer for 3/8" Screw Size, 0.406" ID, 0.875" OD	McMaster 92141A031	8	
7	Wrist Joint	Clevis Rod End, 3/8"-24 Thread, 2-1/2" Shank Center Length	McMaster 6071K14	2	Drill inner threaded hole to 3/8" diameter
8	Threaded Rod Cover	Heat-Shrink Tubing, 0.38" ID Before Shrinking	McMaster 7856K46	2	As long as links.
9	Compression Spring	Compression Spring, 0.59" Long, 0.671" OD, 0.527" ID	McMaster 9657K494	2	Spring rate can be changed for different applications
10	Magnet for locking links to frame.	Neodymium Magnet, Magnetized Through Thickness, 1/8" Thick, 3/8" OD	McMaster 5862K104	2	Attached to side of Frame
11	Rubber Sheet	N/a	N/a	-	Glue on Bottom of Plates
12	Bottom Plate	3D Printed (FDM)	N/a	2	Material: PLA 30% Filling or ABS 20% Filling
13	Cotter Pin	1004-1045 Carbon Steel Cotter Pins, 3/32" Diameter, 1" Long	McMaster 90520A104	2	

Fig. 11: Bill of Materials for 1 Assembly