Jar Opening Device for Humans with Rheumatoid Arthritis

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Abstract

Rheumatoid Arthritis (RA) is an autoimmune disorder that affects the lining of the joints causing swelling, pain, and loss of function in joints common in the wrists and fingers. This leads to difficulty in performing daily tasks like the opening and closing of jars and bottles. We hypothesized that an automated jar and bottle opening device would increase the variety of food accessible to individuals with RA. An interview with an individual with RA was conducted to provide insights into the device's design. A motorized Jar and Bottle Opening device (JaBO) was designed that would fixture, open, and close a variety of jars and bottles. The fixturing mechanism was prototyped to begin validation of the JaBO device. To test our hypothesis, a study is proposed to distribute JaBO devices to 10 individuals with RA for one week to determine if the device reduces pain and increases accessibility to foods via a survey. Results of this study could help further improve the design of the JaBO, as well as assistive devices in general to reach broad adoption by both individuals with RA and individuals with reduced grip strength.

I. Introduction

Rheumatoid Arthritis (RA) is an autoimmune disorder that affects approximately 1.3 million people in the United States and about 1% of the global population [1]. RA affects the lining of joints causing inflammation and subsequent bone erosion and joint deformation [1]. Common symptoms include pain, swelling, stiffness and loss of function in joints [1]. Although any joint may be affected, symptoms are most common in the wrist and fingers. There is no cure for RA and the condition can affect people of any age [1]. However, symptoms most commonly begin in middle age. Treatments most include medications known as disease-modifying anti rheumatic drugs (DMARDs) [1]. Physical therapy can ease the effect of symptoms and help adapt a person's lifestyle to living with RA [1]. Dexterous manipulation of objects can become increasingly difficult amounting to a reduction in grip strength and loss of ability to grasp objects with precision [1]. This paper aims to explore the efficacy of using an automatic assistive device to allow a person living with RA to open and close jars and bottles.

A. *Background*

Risk factors for RA include old age (60+), sex (higher incidence for women), genetic predisposition, smoking, and obesity. Numerous factors may cause flares (an aggravation of symptoms) for people living with RA. These include temperature and humidity of the immediate environment, and time of day (some people report increased likelihood at the beginning and end of the day). As such, a person's ability to function and perform typical daily activities is often affected due to the symptoms of RA.

Reductions in Grip Strength: One of the primary effects of RA is a reduction in grip strength and ability to grasp objects. A study by Brorsson et al. found that women with arthritis had weaker hand extension and flexion force and higher overall muscle activation than the reference group. The women with arthritis had an average 69% the finger extension strength and 33% the finger flexion strength of the reference group [1]. Researchers studied the muscle activation levels of subjects using surface electromyography (sEMG) during various daily activities and hand exercises. Additionally, subjects self-reported their hand function using the Quick Disabilities of Arm, Shoulder, and Hand (Quick DASH) measure.

Tangible Impacts: People living with RA exhibit impaired hand grip function due to pain, reduced muscle strength, and/or hand deformation [1]. Common tasks such as holding a pen, locking a door with a key, cutting with scissors, pulling a zipper, grasping jars and bottles to close/open lids are all difficult to complete. A study by Thyberg et al. found that RA patients were most limited in eating and drinking related tasks such as cooking and opening jars and bottles [2]. It also showed that people with more severe arthritis were more likely to use assistive devices and that the assistive devices decreased the difficulties of these tasks. Yoxall et al. conducted a study of various healthy individuals attempting to open a 75mm diameter jar and lid device. They found that the average torque required to open a jar was 3.2Nm. Even for healthy individuals, women above age 75 were observed to have difficulty opening the jar. Surely for patients of RA, this problem is exacerbated further.

Effectiveness of Assistive Devices: Numerous assistive devices were explored by the team to determine limitations and gaps for improvement. A range of devices such as battery powered, plug in tabletop, and hand-powered products were found such as the Black and Decker Lids Off Jar Opener, the KITCHENMUH Electric Jar Opener, and the OXO Good Grips Jar Opener (Figure 1 below).

Fig. 1: BlackDecker Lids Off Jar Opener (left), KITCHENMUH Electric Jar Opener (middle), OXO Good Grips Manual Jar Opener (right)

Unfortunately, none of these devices were catered towards the needs of an RA patient. In particular, they required dexterous manipulation to attach/detach/locate the container or to operate the device and they only opened jars. Our team determined that there was a need to create a device that could both *open and close jars and bottles* of varying diameters and heights using a method that does not require dexterous manipulation from the user.

B. Overview

We hypothesize that an automatic, motor-operated, tabletop device will improve the self-reported ability of an individual living with RA to access items in and use containers such as jars and bottles. The device will require a user to place the container in a centered position and simply press on a button to activate the device. An individual living with RA was interviewed (see Section II below) to determine daily challenges and needs. The individual highlighted pain and loss of functionality with their hands. To test this hypothesis, we present JaBO (Jar and Bottle Opener); an assistive, tabletop product to automatically close and open jars and bottles.

II. Preliminary results

In order to inform our design, we started by interviewing an older individual with rheumatoid arthritis for over 30 years. We performed the interview over Zoom discussing how RA affects their daily lives, specific tasks, and how they currently address their condition. The interviewee requested not to be on camera, therefore we relied on their descriptions of their activities rather than any visual observations.

Throughout the interview, the interviewee highlighted that RA has severely impacted their daily life. They stated that it causes pain in their joints and limits their range of motion to the point that they cannot raise their arms about their head. They also tire quickly and have very little strength in their hands, wrists, and arms. The interviewee has tried several medical treatments, however none of them have had a significant impact on reducing their RA symptoms particularly pain.

Due to the pain and reduction in grip strength, they described having difficulty opening bottles and jam jars. On one occasion, they specifically cited that they had broken their teeth attempting to open a pill bottle. As a result, the interviewee has to rely on help to open bottles or jars and has said that if they cannot open that type of container, they simply will not eat that food.

This highlighted their desire to have more independence. Because their condition is fairly severe, the interviewee relies on a mixture of family, friends, and hired help to perform household tasks. This lack of independence has extended to create feelings of uselessness because they are not able to do their own cleaning or things they enjoy like baking. One particular area of concern was that the interviewee stated they have help now but were concerned what would happen if they did not in the future.

From this interview, we gained insight into how severely RA can affect people's lives and create a broad set of needs. A brief summary of some of these needs is in Figure 2 below and a more complete list can be found in Appendix B-A. Based on these core needs, we believe that an assistive device that can open and close jars and bottles could provide benefit for people with RA by allowing them more access to different foods, independence, and potentially the psychological security of being less reliant on other people.

Customer Statement	Interpreted Need
Assistive devices don't aid in pain relief.	Pain Reduction
I broke a few teeth trying to open a bottle	Increasing Hand Strength
I can't reach my head very well.	Improving Reach
I have help now, but in the future I may not.	Increasing Independence
I can pick things up or write if my elbows have support	Reducing Long Term Strain

Fig. 2: Table of Customer Needs

III. Methods

A. Design Concept

The device consists of three major subsystems, each powered with a separate DC motor. A gripping mechanism grips the bottom of the container tightly, while a similar mechanism grips the lid of the container. A geared shaft twists the top gripper once the container is fully fixed in order to open/close the lid.

The gripping mechanism is powered by a motor that rotates a pulley which pulls two strings. Each string is routed through the device and attached to two prongs that grip opposite sides of the container. As the motor rotates, the prongs are pulled closer to the container until they lock against the container sides. Springs push the prongs backwards away from the container once the motor rotates in the opposite direction, releasing the grip on the container.

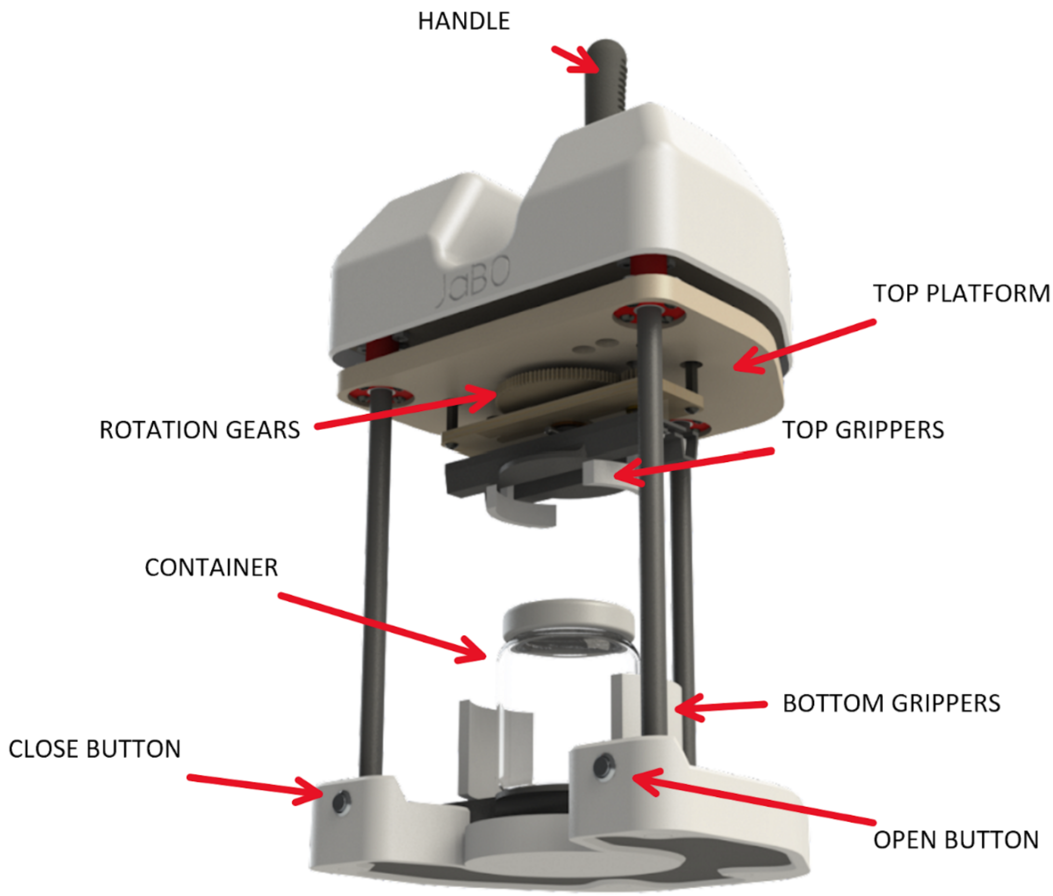

Fig. 3: Initial prototype device concept render.

The opening/closing mechanism is powered by a motor that rotates a geared shaft. The drive gear meshes with a larger follower gear that attaches to a second rotating shaft. The top gripping mechanism is fixed to this shaft with a pin and rotates when power is given to the motor.

The operation of the device is simple. The user first raises the handle on the top of the device, raising the upper platform above the top of the container to be opened. Next, the container is placed onto the bottom platform of the device and the handle is lowered so that the top gripper rests on the container lid. Finally, the user presses the “open” button on the front of the device and the container is opened. The user can raise the handle and take the jar. If the user would like the machine to close the container lid, they can leave the lid inside the top grippers. To close the lid onto the container, the user simply repeats the process described above and presses the “close” button on the front of the device.

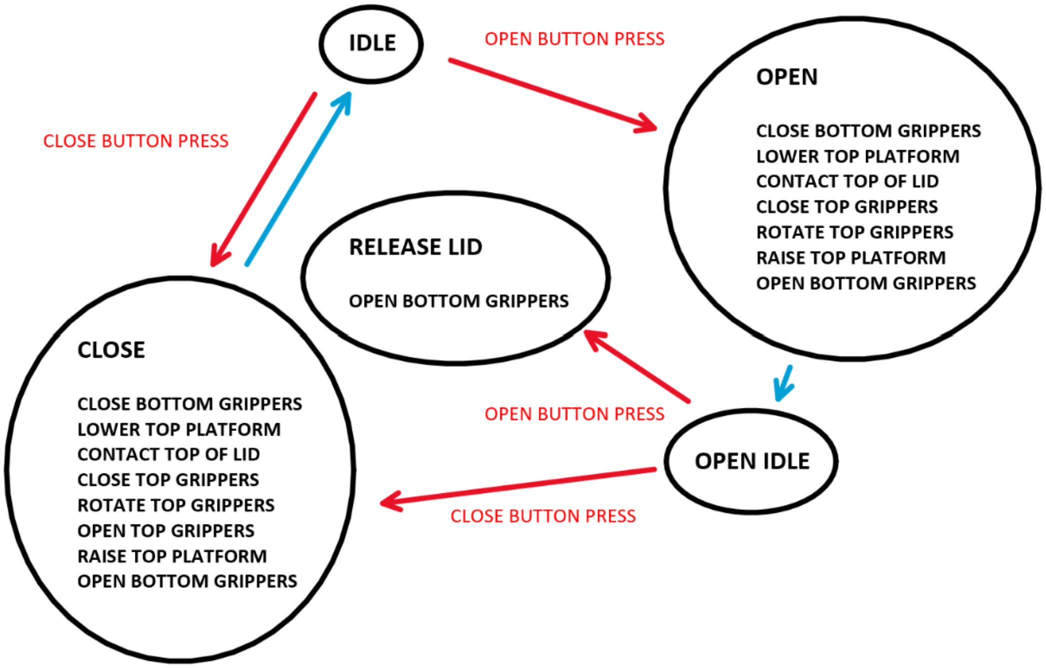

Fig. 4: Device prototype state diagram.

B. Built Subsystem

Given time and cost constraints, we were unable to complete a full prototype shown in the previous images. Our team decided to focus on the bottom gripper subsystem, complete with buttons and a motor to grip a container. For our demonstration, we would open and close the container lid ourselves.

Fig. 5: Prototype at the Jacobs Design Showcase.

Most parts were 3D-printed, including the bottom enclosure, the grippers and gripper frame, the motor mount, the pin enclosure, and the string spool. Each part was mounted to a ½" MDF board that was cut using a CNC Shopbot machine. Fasteners and nuts held parts to the MDF board.

The gripping mechanism worked well, but had some drawbacks. Linear motion presents a lot of difficulties, including tight tolerances and binding. We spent quite a bit of time filing the gripper frame to allow the grippers to slide smoothly back and forth. After adding lubrication, we still found that the grippers were a little stiff. However, the springs were able to effectively return the grippers to their open position. Additionally, we believe a lot of friction is created by the string running through two holes in the gripper frame. The string is able to rotate easily around the stainless steel pins, but the two 3D-printed holes limited the amount of force the motor was able to transmit to the container. In the future, we would like to add a modification so that another pin is used instead of the two holes.

Fig. 6: The holes for the string to route through the gripper frame may be increasing the friction of the system.

Our prototype was effectively able to demonstrate our vision and worked well at the Jacobs Design Showcase.

C. Proposed Study

To validate our hypothesis, we propose a survey-based field study that will give 10 individuals living with RA access to our device for one week and determine if it is both useful and lowers discomfort caused by inflammatory pain.

Participants with any number of years spent living with RA will be selected for the study. Beforehand they will take a survey that asks how often (if at all) they use certain containers like jars or plastic bottles. Next, a device will be shipped to participants with instructions on its use. The system will automatically log each time the device is used to open or close a container. After one week, the device will be retrieved and participants will take a follow-up survey asking if the increased or decreased their usage of jars and plastic bottles, and if their pain levels decreased. Additionally, there will be room for the participant to leave open feedback for future improvements.

IV. Intellectual Merit

With this device and the proposed study, we can evaluate the effect of improved access of jarred or bottled products on the independence and psychology of individuals with RA. We can also evaluate how effective this device is at increasing access indirectly by determining how often the device is used. This device can be used to help improve features of fully motorized assistive opening devices to increase their adoption and usage.

Research has shown that assistive devices can have a large impact on restoring normative functionality to people with RA [2]. Therefore future studies with this or similar devices can focus on how fully motorized assistive devices usage compares to body powered devices for opening bottles and jars. This can help determine if particular demographics benefit more from a particular style of device. One benefit of the automated device is that the number of uses can be automatically tracked to determine if the device is being used often. This can help to track trends for example if use of the device drops off over time due to factors such as inconvenience, ease of use, or other negative experiences rather than being solely based on users' memory of how frequently they use these types of devices.

V. Broader Impact

This device illustrates how assistive devices can be used to access items in jars and bottles resulting in increased independence of people with RA. In the future, this device could be sold as a commercial product and used by anyone with difficulty opening and closing jars and bottles. Older adults may particularly benefit from this type of device because grip strength tends to decrease as people age even without RA. This device could be designed like other kitchen countertop appliances, so that it does not stand out as a specifically assistive device. Targeting a wide audience and incorporating a sleek design would help to reduce potential stigma associated with needing an assistive device and increase the number of people that could benefit from it.

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Appendix A
Discovery Decomposition

Topic of the interview: Rheumatoid Arthritis

1) *Differences in muscle activity during hand-dexterity tasks between women with arthritis and a healthy reference group:* [1].

Brorsson, et al. studied the differences in extension and flexion of women with arthritis and a healthy reference group. They measured the muscle activation of women with rheumatoid arthritis, hand osteoarthritis, and a reference group by performing hand exercise and daily tasks using surface electromyography. They were able to measure the percentage of muscle activation each participant used to perform each task. The study found that women with arthritis had weaker hand extension and flexion force and higher overall muscle activation than the reference group. The women with arthritis had an average 69% the finger extension strength and 33% the finger flexion strength of the reference group. Writing and cutting with scissors had the highest muscle activation of the tasks tested across all groups.

2) *Survey of the use and effect of assistive devices in patients with early rheumatoid arthritis: A two-year followup of women and men:* [2].

Thyburg, et al. sought to identify activities that were limited by rheumatoid arthritis, patients that needed assistive devices, and the effectiveness of assistive devices. A survey was conducted of patients diagnosed with rheumatoid arthritis. This survey asked patients if they experienced pain, limitations, or difficulty in various daily activities over a two week period. It asked patients to report their solutions to their difficulties performing these tasks. The results showed that most women and men did not experience difficulty in most of their daily activities. The most common activities that were limited by rheumatoid arthritis were eating and drinking related tasks such as cooking and opening jars and bottles. It also showed that people with more severe arthritis were more likely to use assistive devices and that the assistive devices decreased the difficulties of these tasks. Patients that used assistive devices tended to have 3 to 5 different devices.

3) *Age and grip strength predict hand dexterity in adults:* [3].

In 2015, Martin et al. conducted a study about aging, hand strength, and hand dexterity. It's been previously found that there is a relationship between aging and reduced muscle strength but a lack of significant research investigating a relationship between aging, strength, and hand dexterity. 107 adults ranging between 18 and 93 years completed numerous hand dexterity tasks as well as a grip strength test. A "Vienna Test System: Motor Performance Series Workboard" was used to measure dexterity on an objective score from 0-100 (depending on the task) while grip strength was measured in kg using a handgrip dynamometer. Age and muscle strength both correlated with variances in hand dexterity results, but age played a larger role in the performance of steadiness and tracking tasks while strength played a larger role in the performance of aiming and tapping tasks. The authors hypothesized that since strength isn't as great of a predictor in steadiness and tracking tasks, it's believed that muscle control/tremor may be a large factor in these types of dexterity tasks.

4) *Hold, grasp, clutch or grab: Consumer grip choices during food container opening:* [4].

In 2011, Rowson and Yoxall conducted a study on grip strength and choice for opening jars. Consumer packaging can be difficult to open for a rapidly-growing elderly population. This study was carried out in order to determine if different grip types when opening consumer jars are stronger than others and if users choose to use the strongest grip type or instead choose to use the most comfortable. Grip choices and associated torque values were measured using a grip-testing device. It was found that lateral grips, although the most comfortable grip, generally do not allow for sufficient torque for women to open jars. It is now known that to improve the likelihood of women opening a jar, the required torque must be reduced or the frictional coefficient be increased.

5) *Finger friction: Grip and opening packaging:* [5].
In 2007, Lewis et al. conducted various tests to measure skin friction. Grip and finger friction are critical parameters to perform daily activities and manipulate objects yet there is very little documentation of skin friction factors, especially for static friction coefficients. A rig was developed to measure finger friction against various packagings such as bottles and jars with variations in conditions made with wet vs dry vs oily conditions. The static friction coefficients in tests with a friction measurement rig and a bottle opening rig. Oily conditions greatly increase the difficulty to open a bottle whereas wet conditions decrease the difficulty. Adults up to the age of 70 (males + females) will have no difficulty opening the bottle (except in the presence of oil) and females above 71 will have difficulty, even in dry conditions.

6) *Juvenile Idiopathic Arthritis:* [6].
In 2005, Weiss and Ilowite extensively summarized the condition of juvenile idiopathic arthritis. JIA includes a group of disorders that are the most common chronic rheumatic illness in children. An article was written to overview the classification, diagnosis, and treatment of JIA as well as a discussion on the outcome of adults that continue to struggle with the disorder. Three systems are used that can classify patients with chronic arthritis under 16 years, each using clinical features that classify the disease and the disease subtype. JIA can continue into adulthood and has a profound impact on their livelihood and employment. Treatment includes controlling pain, inflammation, promoting normal body growth and has improved recently with advances in antirheumatic agents and better therapy techniques.

7) *Openability: Producing Design Limits for Consumer Packaging:* [7].
In 2006, Yoxall et al. collected quantitative data for torque measurements of various adults. The average age for people (UK demographic) is increasing which means that the average strength of the population is decreasing. Since conventional packaging methods such as glass jars and bottles are unlikely to change, they must be designed to be opened easier. 235 people (of various ages and both genders) were asked to open a human torque measuring device resembling a jar. The maximum torque that each person can apply to the torque measuring device was measured. Results loosely matched some previous studies that showed much of the female test subjects would not be able to open some jars and males over the age of 75 will also struggle. A quantitative measure of the lowest applicable torque for opening jars has been further validated (some earlier studies had similar results) such that new jar designs can adhere to opening torque specifications.

8) *Requirements for packaging from an ageing consumer's perspective:* [8].
In 2008, Duizer et al. surveyed various packaging attributes and consumers attitudes towards them. With an increase in the percentage of aging consumers, packaging considerations and expectations must shift to accommodate these consumers. Ninety-nine individuals (over the age of 60) in New Zealand were surveyed to determine packaging attributes of importance when selecting food products. Participants were surveyed and their importance for product packaging attributes was measured (such as opening type, price, shape, etc). Participants stated that price, safety, pack size, and recycling were important factors for choosing food products. In order to satisfy the demands of the aging consumer, food products should be packaged in small containers. These containers should have lids large enough to be able to easily remove them with hands that may have muscle weakness.

9) The Effect of Jar Holding Posture on Finger Force and Torque during a Jar-Opening Task for Young Females: [9].

In 2007, Huang et al. investigated the effect of holding posture on the ability to open a jar for young females. The elderly are known to have such problems due to their relatively low strength and dexterity; however, few studies have investigated the problems encountered by healthy adults, particularly young women (¡25 yr old). Twelve healthy, right-handed females were requested to open a jar simulator. Directions and magnitudes of the thumb, index-middle finger group, and the ring-little finger group were measured for each participant. The free-way opening posture allowed participants to produce a higher torque versus the vertical opening posture (jar on table).The free-way opening posture (two hands held in front of chest) is the better strategy for young females to open a jar.

10) A biomechanical analysis of finger joint forces and stresses developed during common daily activities: [10].

In 2011, Butz et al. conducted a study on hand joint forces. Osteo and rheumatoid arthritis affect large portions of the global population and create pain and swelling in the knees, wrists, and hands. The study aimed to extend existing literature methods to understanding stresses placed on the hands and fingers during commonly performed tasks. Joint forces in the PIP, DIP, and MCP joints were measured for five different everyday tasks: keyboard typing, playing piano, gripping a pen, carrying a handled bag, and opening a jar. Jar turning with a cylindrical grip resulted in the largest forces on the DIP and PIP joints out of the five tasks. It is now known that common activities may have a strenuous effect on hands and their respective joints. These activities could influence degenerative diseases like arthritis.

11) Designing Inclusive Interactions - Chp 5: Accessibility is in the Palm of Your Hand: [11].

In 2010, Yoxall et al. compiled papers from the Cambridge Workshop on Universal Access and Assistive Technology for that year. In chapter 5, they discussed the design of containers that exclude children but enable older adults to still access contents. Child resistant closures (CRCs) prevent children from accessing the contents of a container (such as medication) but they also exclude the elderly (65+). 60 adults from the age of 19-71 were asked to observe, open and reflect on the experience of opening: a) a normal 'push and turn' pill bottle, b) a new bottle without ridges, and c) a new bottle with ridges. For a second test, a rapid prototyped bottle design was used to encourage palmar grip. The grip choice and openability was observed for each participant. Changing the geometry and affordances of the exterior shape of the pill bottle led to a significantly higher adoption of palmar grip (as opposed to lateral or cylindrical grip). Changes to the geometry and affordances of a product could lead to changes in the way they are gripped and hence opened. Pill bottles designed this way can retain exclusion of children while allowing a larger population of the elderly to access the contents.

12) Circadian rhythm in pain, stiffness, and manual dexterity in rheumatoid arthritis: relation between discomfort and disability.: [12].

In 1991, Bellamy et al. conducted a study on circadian rhythms affecting rheumatoid arthritis. Previously, circadian variation had been reported as a variable in both clinical and laboratory studies in patients with arthritis. Statistical techniques including least squares and coside vector analysis were used to determine a relation between the relative timing of pain, stiffness, and disability in subjects with rheumatoid arthritis. Subjects were asked to rate both their stiffness and pain on a physical analog scale after performing a "bead intubation coordinometry" (a manual dexterity) test. Pain, stiffness, and testing performance correlated with each other and sinusoidally changed throughout the day with morning and nighttime hours exhibiting the greatest pain/stiffness and poorest testing performance. It was then suggested that time of testing should be tightly controlled during rheumatoid arthritis clinical trials.

13) Recovery of Ipsilateral Dexterity After Stroke: [13].

Sunderland studied the dexterity of individuals 6 months after stroke. It is known that stroke patients often initially have limited dexterity immediately after the stroke but that it can improve over time before leveling off. This study used several standardized tests to measure dexterity as well as interviews with the patient and close relatives on the effects in everyday tasks. It was found that the patients' dexterity improved to perform all of their daily tasks if given enough time, despite measurable decreases to their dexterity. This resulted in less reporting of impaired function because patients were able to still complete all of their normal activities. Factors such as grip strength returned to similar values as the control group.

14) Impairment of fine motor dexterity in mild cognitive impairment and Alzheimer's disease dementia: association with activities of daily living: [14].

Paula, et al. studied the effects that mild cognitive impairment and Alzheimer's disease dementia have on fine motor dexterity. This study used the Nine-Hole Peg test to measure the fine motor skills of participants with mild cognitive impairment, Alzheimer's disease, and a control group. It was found that people with mild cognitive impairment had slower motor responses than the control group and members of the Alzheimer's group had even slower responses. It is suggested that the slower response combined with the cognitive impairment would lead to more difficulty in daily tasks.

15) Dexterity Performance and Reduced Ambient Temperature: [15].

Riley and Cochran studied the effects of cold temperatures on dexterity. Male and female subjects performed several dexterity tests and tasks at temperatures of 23.9°C, 12.8°C, and 1.7°C. The researchers measured the accuracy and time it took to complete the tasks at the different temperatures. It was determined that there was no significant difference in dexterity between tasks performed from room temperature (23.9°C) to 12.8°C. Dexterity did decrease in the 1.7°C environment. Skin temperature measured on the small finger measured the decrease in temperature on the hand. It was also noted that the most severe decrease in dexterity involved the task to assemble an electrical box involving complex gross movements and fine rotational movements.

APPENDIX B
INVESTIGATIONAL DEVICE DETAILS

A. Hierarchical List of Customer Needs

- Increase hand strength (may be task specific)
  - Product squeezes out toothpaste with little strength required.
  - Product presses spray bottle trigger with little user input force.
  - The product needs to be lightweight
  - Assist in gripping object such as jars
  - Assist in holding a cup/mug
  - Assist in removing a power cable from a cell phone
  - Grip needs to be improved
- The product improves arm reach
  - Product brushes hair without requiring user to raise arms
  - Assist in raising arms (at least till head height)
  - Product assists in pulling socks onto feet.
  - Product aids in fastening shoes to feet.
- Product reduces pain.
  - Product changes temperature.
  - Product becomes hot and cold for pain relief.
  - The product reduces joint pain
  - Product is comfortable to wear.
- The product reduces strain over long time periods
  - The product supports the arms
  - Product raises elbows for user on command with minimal user force.
  - The product reduces the load on joints
  - Product aids in holding heavier items up.
  - Product helps interact with machines and require less force to use.
  - Product provides powered transportation to reduce walking strain
- Increases independence
  - ”Promote independence such as with walking or upper limb exercise
  - Assist in breakfast making”
  - The product improves access to food containers

B. *Brainstorming*

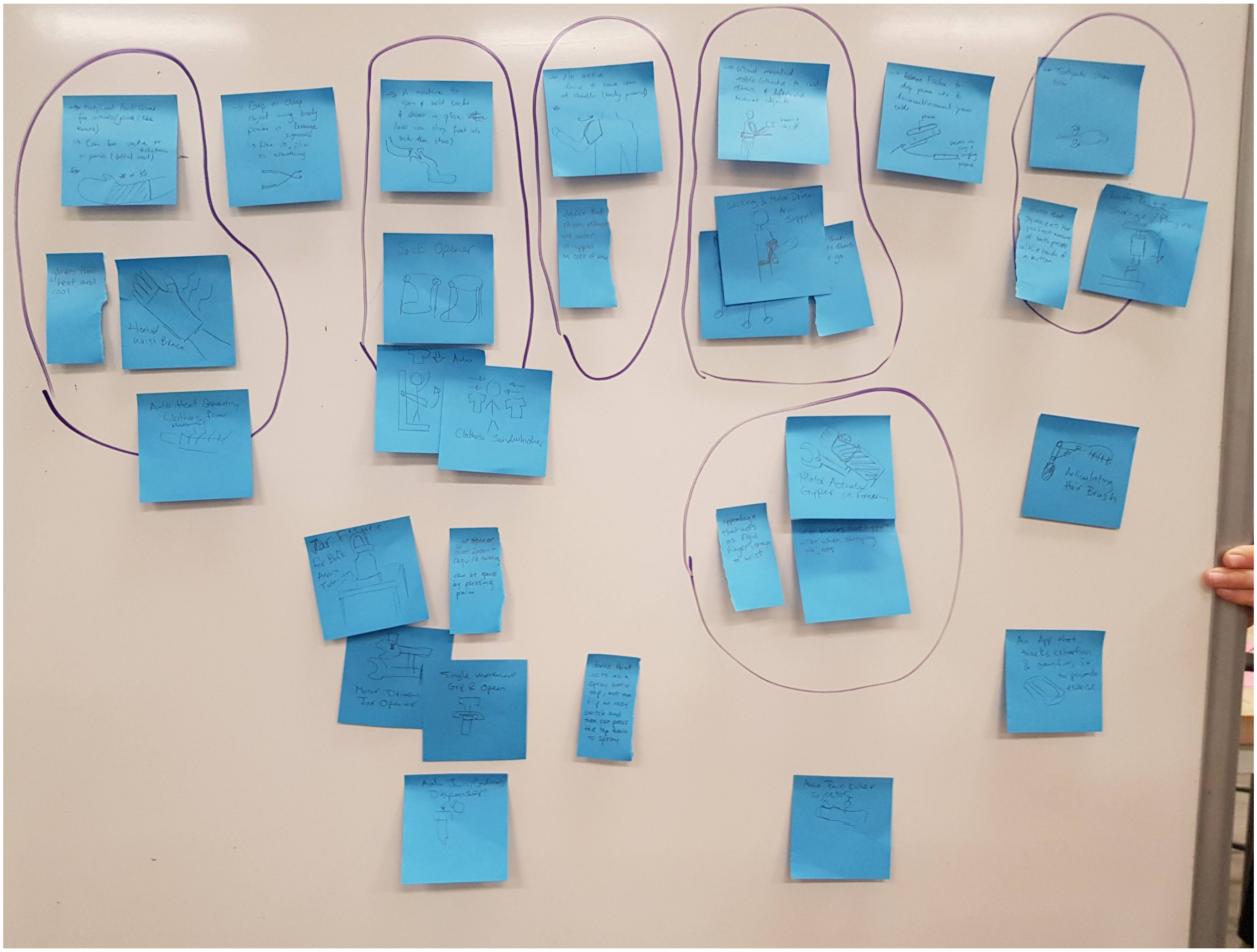

Fig. 7: Image of Brainstorm of Potential Products and Solutions

C. Concept Scoring

Team Average Weighted Matrix	Increasing Hand Strength	Improving Reach	Pain Reduction	Reducing Long Term Strain	Increasing Independence	Feasibility	Desire	Complexity	Score
Wearable Temperature Control Devices for Wrist/Hand	1.67	1.33	4.33	3.00	2.67	3.00	1.33	2.33	5.04
Dressing Assistance Devices	1.00	2.33	2.33	1.33	4.33	2.00	1.33	2.33	4.19
Upper Limb Actuation/Relief Devices	1.67	3.67	2.67	3.00	2.67	2.67	2.33	2.00	4.99
Arm/Elbow Support/Resting Devices	2.00	3.00	3.00	3.67	3.00	3.33	3.33	3.33	6.16
Toothpaste Delivery Devices	2.00	1.00	2.00	2.00	3.00	4.67	3.67	4.00	6.18
Food Dispensary Products	2.67	1.33	2.00	2.00	4.33	3.67	3.33	3.00	5.81
Jar Opening Devices	4.67	1.67	2.00	1.67	4.00	4.67	4.67	3.67	7.24
Articulating Hair Brush	1.00	4.33	2.67	2.67	2.33	3.33	2.33	3.00	5.45
Exercise/Therapy Gamification App	1.67	1.67	3.00	3.67	2.67	1.33	1.00	1.67	3.81
Spray Can Assister Tool	4.33	1.33	1.67	1.33	2.33	4.33	3.33	3.33	6.07
Pain Killer Reduction Brace (Chemical Solution)	1.67	1.67	5.00	3.00	2.67	1.00	1.00	1.00	3.96
Grip Assist Arm/Appendage Attachment	4.67	3.00	2.67	2.67	3.33	2.67	3.00	3.00	6.20
Phone Fixture/Charging Assist	2.00	1.67	2.00	1.00	2.67	5.00	2.33	4.33	6.01
Criteria Weights (0-1)	**0.24**	**0.18**	**0.29**	**0.11**	**0.18**	**0.40**	**0.27**	**0.33**	

Fig. 8: Scoring Matrix of Concepts

D. Final Product Detailed Renders

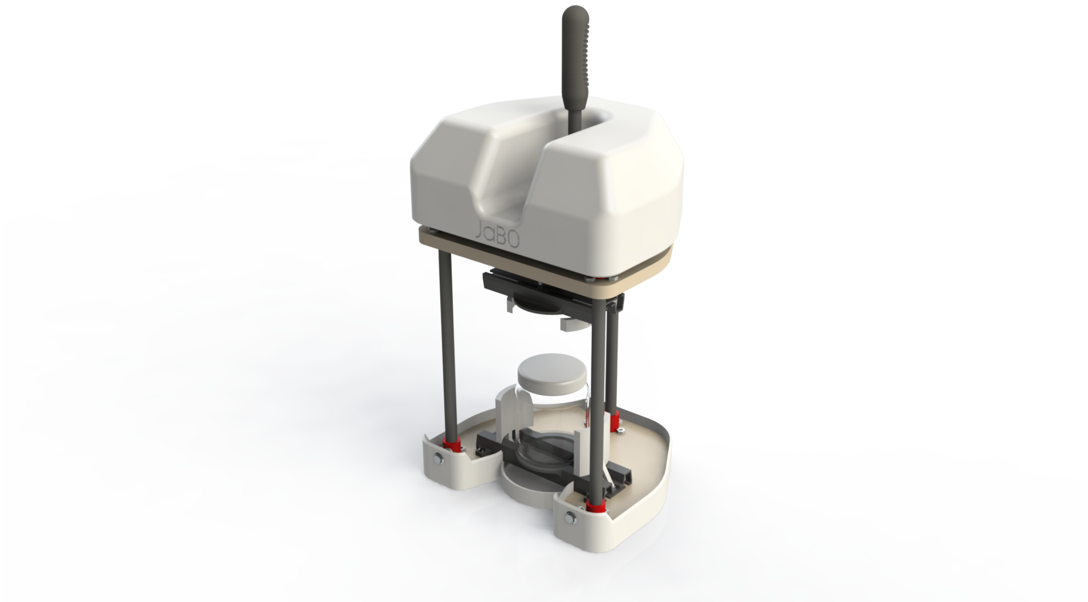

Fig. 9: JaBO Isometric View

Fig. 10: JaBO Front View

Fig. 11: JaBO Rear Isometric View