Assitive Bottle Opener for Rheumatoid Arthritis to Decrease Joint Stiffness

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Abstract

Rheumatoid arthritis, RA, is an autoimmune disease that attacks the body's tissues, leading to joint stiffness, pain and other symptoms. Currently, there is no cure for RA and people with RA require medications such as disease modifying anit-rheumatic drugs (DMARDs) to help manage the symptoms. However, in many cases, these are not sufficient or fail to help alleviate the symptoms and require the person to seek outside assistance through devices or relatives [1]. To better understand the use of assistive devices in the RA population the team interviewed a need-knower to gather their insights and identify unaddressed needs, specifically pertaining to this need-knower. A device was then proposed to determine whether the size of the device would address the need-knower's primary needs and a series of tests were proposed to understand and quantify the frequency of use of the proposed device and determine how it could impact the scientific community as well as the RA community.

I. Introduction

Affecting 1 of every 200 adults worldwide, rheumatoid arthritis (RA) is an autoimmune disease in which the body's immune system attacks the joint lining in the body. RA can affect anyone at any age and the cause is unknown. RA causes joint inflammation, most commonly in the hands, but can affect any part of the body, which can lead to damage to other parts of the body, as well as physical disability and deformity. The damage to the tissue can also lead to chronic, long-lasting pain, joint stiffness, fatigue and weakness. Patients are often lose strength in their hand, making them unable to open jars and bottles and reduce their range of motion. RA is often treated with disease-modifying antirheumatic drugs (DMARDs) to decrease disease activity or get the patients to go into remission, the goal of RA medication centers around management. There is currently no cure for RA, but early diagnosis and treatment can help reduce the progression of damage and reduce the chances of RA-related disability [2],

A. Background

Current RA management strategies rely on the use of DMARDs, such as Methotrexate and Sulfasalazine,non-steroidal anti-inflammatory drugs (NSAIDs), and other forms of drug treatments to help people with RA at a physiological level [3]. DMARDs are meant to interfere with the RA, target inflammation and inhibit the progression of joint damage. There are many subdivisions of DMARDs used today and are some of the main drugs used to stabilize RA. NSAIDs are drugs used to reduce pain and swelling associated with RA, but are not disease modifying. The goal is to begin using them early to help in stabilizing and reducing the probabilities of physical deformities. The DMARDs and NSAIDs are typically used in conjunction with one another, as this has shown to have better outcomes than using a single DMARD treatment strategy. Treatment strategies can vary depending on the goals of the person with RA, for some the goal is to make the RA go into remission, while others want to decrease disease activity enough to not interfere with their daily living. However, in some cases, symptoms are still experienced or immunity to medication is developed [1].

On the other hand, there are also assistive devices that are used to help the user regain some independence by giving them the ability to perform tasks they weren't able to before. Currently, there's very little data on the possession and adherence to assistive devices with possession rates ranging between

34%-78%. The most common assistive devices among those with RA are mobility devices and the less-frequent usage devices are adaptations for housing. Quantifying usage has been difficult in literature and many factors need to be accounted for, such as convenience, usefulness and RA progression [4]. In the market, there is quite a variety of assistive devices for RA that address different needs and exploring the usage of these devices can help us understand how to help those with RA regain their independence. We hypothesized that discreteness, in this study meaning size, will increase the frequency of tool use in the RA population. In surveying subjects, we expect to find that they report the device as more discreet when the size is smaller. As a consequence we also expect the subjects to report the device to be more convenient, resulting in higher usage and a reduction in joint stiffness/soreness throughout the day.

B. Overview

In the following section, Section II, we will introduce and dissect an interview case study with a person with RA that has guided the design and engineering process. Section III will describe the proposed device and the methods through which it will be tested for real life applications, such as its ability to open jars and frequency of use. In Section IV we will discuss the scientific and engineering implication of the use of our proposed device and how it can guide future research and development. Finally, Section V will discuss the implications and of the proposed device for the RA community and its impact for the general public.

II. Interview case study

To understand the effects and daily life with RA, we conducted a video-call interview that lasted about one hour with a person with RA, hereinafter referred to as "the need-knower". The need-knower lives in a large city, where they live a busy, on-the-go lifestyle. From a very young age RA symptoms became part of everyday life for the need-knower, thus having first hand experience in managing the symptoms. Currently, the need-knower works in an elementary school teaching very young children. They take medication to manage some symptoms and developed a nightly, therapeutic routine to help begin the mornings with as little stiffness as possible.

During the interview with the need-knower, we learned that as the day progresses, the need-knower can feel the joints become stiffer and swell. It was said that in colder environments this stiffness begins to set in earlier in the day and is accompanied by joint pain. The joints in the hands, as well as the knees are what are affected the most, making dexterous manipulation tasks and crouching and kneeling harder. The need-knower informed us that as time has gone by, they have begun losing strength in their arms, making tasks more difficult to complete, such as cutting and opening bottles, oftentimes requiring the need-knower to ask for assistance.

The need-knower expressed that pain management has become a low priority because throughout the years they have learned to tolerate it. The ability to retain their independence and be self-sufficient is what is most important to them. They would like to be able to limit the amount of times they ask for help and thus, limit the amount of times they have to explain their RA to others because this is an uncomfortable topic to discuss with others. One of the tasks the need-knower would like to do on their own is opening bottles/jars as this is something that they have to do for their class daily and the need-knower has to rely on an assistant to be able to do this for the class. However, the need-knower emphasized the importance of discretion and convenience. They want to be able to incorporate it seamlessly into their routines and not attract too much attention and questions, these are summarized in Table I. Overall, discretion and convenience is important in a device that is meant to help them make up for the loss of strength in their hands.

III. Proposed Device & Test Methods

A. Proposed Device

The proposed device is a self-locking expansion mechanism that is placed on top of bottle caps/lids to aid in opening them. The device is composed of a central gear, a base, gripping pincers, a coupling

Primary findings	Interview statement	Interpreted need
Loss of strength	"I need help doing certain tasks, because I physically don't have the strengths for it."	Values independence. Doesn't want to HAVE to ask for help
Likes/needs convenience	"It shouldn't take too much time to execute"	wants something fast and simple
Doesn't like to bring attention to their RA	"they would think like, I'm just pretending I can't do things"	Doesn't want to have to explain or defend the RA symptoms

TABLE I: Interpretation of interview findings based on interviewee statements.

handle, and a casing. Figure 1 and 2 represents an overview of the device. The mechanism functions by shifting the lever either clockwise or counter clockwise to direct the rotation of the central gear, which is attached to the pincers, causing them to either open or close, respectfully. The pincers are augmented with rubber tips which will increase the friction when in contact with caps/lids. Additionally, a shifting guide is used to keep the lever in place when rotated, to avoid any recoiling made between the pincers and the object. Once a tight grip is made, the user can then twist the device from its handle on the casing to twist the cap/lid. Due to the handles width and structure, less force would be needed to twist than compared to if the user were to open cap with their hands, thereby aiding the user to open the cap/lid. Additional detail (like design files for replication) will be in the Appendix A.

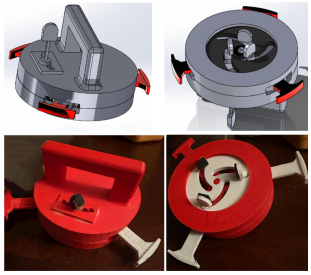

Fig. 1: CAD images (above) and prototype images (below)

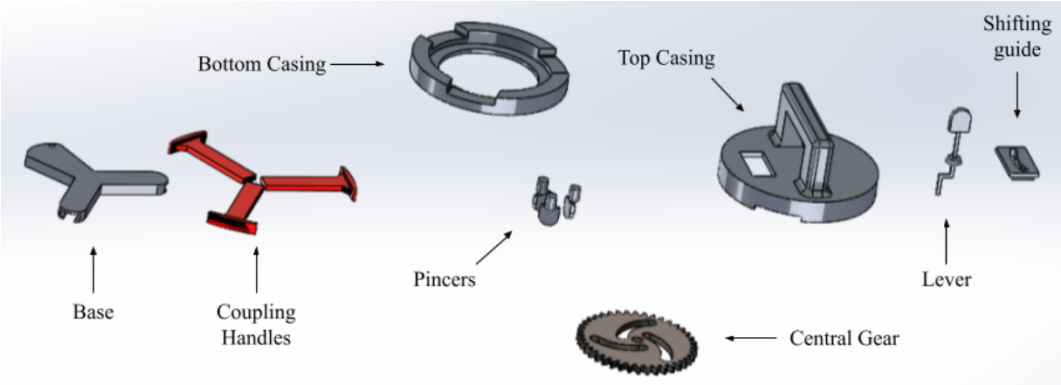

Fig. 2: An exploded view of the device with all parts visible and labeled

B. Test Methods

Testing of the device will consist of benchtop testing as well as human subjects testing, first to test the mechanical properties of the device and then to study the frequency of usage of the device.

During the first phase of testing, the team will assess the ease at which the components are able to 1) move smoothly with one another, by simply pulling on the pulley systems and then pushing them back to their original position. During these trails, we will observe if the pins and pulleys are able to move

to their positions without any obstructions or difficulties. Once that is confirmed, we will then move on to assess 2) whether the device is able to grasp caps and have enough strength to open them. We will primarily focus on plastic water bottles, but also test on other lid/cap sizes to identify its limitations. The device will be opened by pulling on the pulleys, then it will be placed on the water bottle and close the device to see if the device is able to grasp the bottle. If it's able to grasp the bottle then we will turn the device to attempt to open the bottle. If successful, we will move on to field studies, if not further design adjustments will be needed.

Once the device is able to successfully open the water bottles, then we will perform field studies by recruiting the need knower as our first subject. We will attempt to capture the need-knower's routine, incorporating the device, by using video cameras that will be set up in the classroom to record the amount of times the need-knower uses the device and during what tasks, if other than opening water bottles. We will also use surveys to assess the need-knowers inner thought on the device, whether they found it easy to use, if they considered using it, and if questions were asked regarding the device from others. This study would last about a week to fully understand the frequency of use, the need-knower's perception of the device and help us predict whether the device will be incorporated into the need-knowers everyday routine.

The use of video recordings and surveys will help us understand our proposed device, but because identifiable data will be collected in the form of video footage, it's important that we store this information in a secure drive that only the team can have access to in order to protect the need-knowers identity, as well as any person that may appear in the footage, considering it will be taken in a public place. The surveys will also be stored in said drive and once the data is collected and we no longer require it, the data will be permanently removed to protect the need-knower's identity. It may be beneficial to expand this study to other people with RA to see how they would incorporate it in their lives and if it will be beneficial to them as well. A similar process will be done for other subjects.

IV. Intellectual Merit

Much research is being done on DMARDs, their formulations and strategies in prescriptions. However, with this proposed device there is an opportunity to study the conservation of forces in people with RA when aided by external forces. This study can be a precursor to future assistive device studies pertaining to frequency of use to further understand the factors that influence usage, help better quantify these elements and understand how to optimize device design for this population. There is a need for more concrete data on the usage and possession of assistive devices for RA and being able to collect this data can aid in the optimization of device design, prescription of devices that are tailored to individual needs and possibly incorporate devices for therapeutic benefits. Overall, this could help further understand how to assist people with RA and retain a sense of independence and normalcy in their everyday lives.

V. Broader Impact

RA can severely impact a person's quality of life, causing consistent pain, fatigue and limits the person's ability to be self-sufficient, which can also have a negative impact on their mental health and overall emotional well-being. In the creation of devices such as the one proposed in this paper, the person's self-sufficiency is kept in mind. This device would decrease the amount of activities that the person would otherwise require assistance with, allowing them to feel more independent, as well as reduce the joint stiffness that sets in throughout as the day progresses. Devices that are more discreet, in size, yet functional, will could increase the frequency of use while also avoid unwanted attention. This invention will hopefully influence future work on force augmentation in people with RA in a way that could encompass more than opening bottles/jars, and help improve quality of life.

REFERENCES

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APPENDIX A
INVESTIGATIONAL DEVICE DETAILS

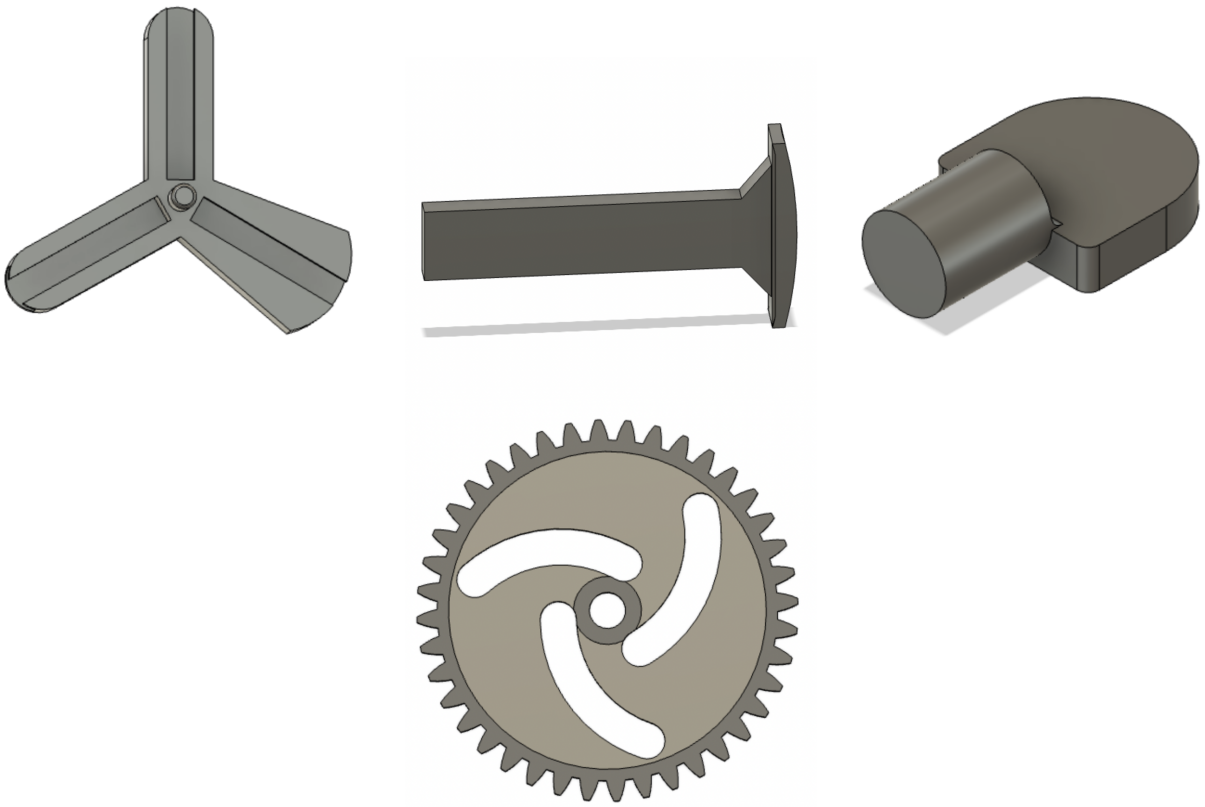

Figure A.1: Mechanism Parts consisting of: the base (top Left), the coupling handles (top center-3), the pincer (top right-3), and the central gear (bottom), mechanism enclosure not included here.