A Preventative Solution for Repetitive Strain Injury

Andrew Plewe, Paul Hsiao, and Tony Ngo
Augmenting Human Dexterity – Spring 2021
Term Project Report

Abstract

Repetitive strain injury (RSI) is one of the most common workplace injuries. While treatment strategies such as physiotherapy can be used in order to reduce RSI symptoms, they are moderately effective at best. An in-depth understanding of RSI in the workplace was developed through an interview with a pharmacist suffering from tennis elbow, tendinitis, and upper-body muscle soreness due to her occupational duties. Using this research, a novel workplace-specific RSI treatment was developed that focuses on the prevention of RSI symptoms. To prove the effectiveness of this device, a workplace study is proposed. This study involves four groups: a control, and three groups that utilize MERA at 33%, 66%, and 100% of their workday, respectively. The workers will be required to document their workplace actions and RSI symptoms. We expect to find a significant decrease in RSI incidences among the workers who use MERA, in comparison to the control.

I. Introduction

Repetitive strain injury is a broad term that describes many disorders that are the result of repetitive motion, and accounts for over half of all occupational-related illnesses in the United States [1]. Common RSIs include carpal tunnel syndrome and lateral epicondylitis (tennis elbow), with common symptoms including burning sensations, muscle weakness, and pain [2]. These symptoms can result in the loss of workdays and high medical costs, and can hamper a person's ability to properly function outside of work [1]. RSI is especially common in the workforce; a 2003 study found that 5.9% of Canadian workers had upper-body (hand, wrist, shoulder, and arm) work-related RSI [3]. These rates of RSI can be as high as 22-40% in specific occupational tasks such as industrial textile manufacturing, construction work, and the loading, unloading, or packing of goods [2]. The goal of our investigation is to determine the feasibility of an assistive device that can prevent repetitive strain injury and ultimately improve the livelihood of those who suffer from RSI symptoms.

A. Background

RSI is caused by a number of physical, work-related, and psychological factors. There is ample evidence that shows repetitive motion, poor posture, poor ergonomics, and inadequate strength all lead to a higher likelihood of suffering from RSI [2]. There is also a strong association between pushing/pulling heavy objects and an increased incidence of upper-body pain and injury [4].

Work-related issues, such as burnout, also play an important role in the development of RSI. A 2012 study of 15,663 South African workers investigated the rates of RSI among three different working groups: (1) highly engaged (i.e. those who had a positive and fulfilling work mindset) but exhausted workers, (2) burned out and exhausted workers, and (3) highly engaged and non-exhausted workers. The researchers found that the first and second groups experienced RSI-related symptoms at a significantly higher rate in comparison to the third group [1]. This phenomenon can be attributed to the increased stress/fatigue and decreased rest periods experienced by burned out workers. Prolonged stress can also result in chronic health problems, such as persistent sleep problems, impeding the healing process and further impacting the severity of discomfort caused by RSI [1].

While there are a number of conservative treatment options (i.e. non-surgical) for RSI, such as braces or physiotherapy, there is currently no strong scientific evidence supporting the efficacy of these treatments [5]. This is primarily due to the poor methodological quality of many of the studies exploring the efficacy of these treatments [5]. In the case of carpal tunnel syndrome (CTS), while many studies have claimed that using a splint, such as the one in Fig. 1, is an effective way to treat CTS, many of the trials are at high risk for selection and performance bias. This is due to methodological failures, such as improper patient randomization or a lack of patient blinding (e.g. patients have the knowledge of receiving treatment in the form of a splint, which could lead them to exaggerate their rating of improvement) [6].

While surgical options can sometimes lead to better outcomes in comparison to conservative treatments, the associated risks are much higher. A 2008 study of 317 patients with severe CTS found that surgical treatment relieved CTS symptoms significantly better than splinting did [8]. However, they also found a much higher incidence of adverse events (e.g hypertrophic scars or stiffness in the wrist), indicating that surgery should be restricted to those who would benefit the most from the surgery (e.g. those with severe CTS).

Fig. 1: An Orfit wrist splint for treating carpal tunnel syndrome [7]

Therefore, since post-injury treatment of RSI is often not highly effective, especially if the patient is not fit for surgery, RSI prevention is often the best intervention strategy [9]. There are a number of ways to prevent RSI from occurring: reducing the stress level of the workers, lengthening and improving rest breaks, or having seminars about proper posture while working. However, we believe that one of the most direct ways to prevent repetitive strain injury is by reducing the muscle forces exerted by the workers.

One commonly studied method to reduce muscle load is through the use of an exoskeleton. In situations such as lifting heavy objects, active/powered exoskeletons are able to reduce the physical load on certain muscles in the forearm by almost 65% [10]. Passive exoskeletons, while simpler in design, are still able to reduce loads in the erector spinae muscles by almost 25% during static trunk bending [10]. However, current industrial exoskeleton technology faces many challenges. These include concerns such as safety (there is a risk that the exoskeleton could get ”snagged” on nearby industrial equipment), decreased user comfort (e.g. heightened pain at exoskeleton-body attachment locations), and a decrease in worker movement dexterity due to the bulkiness of the exoskeleton [11], [12]. Exoskeletons may also be excessive for work environments that require the worker to perform only a few simple repetitive tasks, such as performing the same lifting motion from the same location every few minutes.

Full robotic automation of the workplace is another possibility, but has a couple of key problems that prevent it from being the most viable option. First, it is difficult for fully automated systems to be adapted to a work environment that necessitates a high level of flexibility [10]. For example, robotic systems might be extremely efficient at repeatedly transferring the same part from one station to the next in a large manufacturing plant. However, in a more dynamic environment in which there may be many uniquely-shaped products that need to be picked up, scanned, and sorted, a robotic system would most likely be less ideal. Such an environment is usually much better suited for human workers. Second, full automation is often prohibitively expensive, requiring large changes to the work environment and the addition of highly expensive machinery [10].

B. Overview

From this literature review, we believe that a middle ground device - one that takes the human-machine interaction principles of exoskeletons and combines it with the design philosophy behind robotic automation - could provide a good balance of cost, complexity, and productivity. We therefore hypothesize that using a non-wearable, user-operated, stationary machine to reduce the magnitude of repetitive musculoskeletal loading will reduce the severity and incidence of RSI. A preliminary interview with a worker suffering from RSI, discussed in Section II, reinforces this idea that reducing the amount of repetitive load on the muscles will aid in reducing the risk of developing RSI. In Section III, we describe the development of a novel load-reducing device. This device, specifically designed for our interviewee and her line of work, will allow us to understand whether reducing muscle load during repetitive motions can lower the risk of RSI. If our hypothesis holds true, we believe it could refocus RSI treatment from post-injury remedies, such as physiotherapy, to injury prevention. These findings could greatly impact many workers, as occupational RSI is prevalent in many different industries.

II. Preliminary Results

Our interviewee is a middle-aged pharmacist who suffers from tendinitis, tennis elbow, and general upper-body soreness. During the video call interview, she detailed her daily routine, which she performs while standing at her workstation (shown in Fig. 2) for the entire 8-hour workday. Her primary job is to verify the contents of various prescription medications packed into totes that arrive in front of her station via a conveyor belt. In order to perform her job, she reaches over her workstation, grabs a 5-10 pound tote from conveyor belt 1, and places it on her workstation. Next, she unpacks the tote, verifies and scans the contents of each package in the tote, packs the contents back into the tote, and reaches over to return the tote to conveyor belt 2.

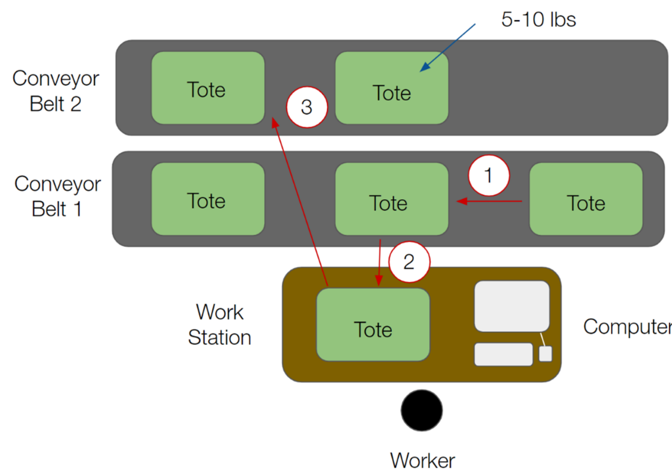

Fig. 2: Interviewee workstation layout

Our interviewee had never experienced tendinitis or tennis elbow until she started working at the pharmacy. However, over the course of her first year at the pharmacy, she gradually started to develop these conditions and the associated symptoms of pain and numbness. These symptoms are often most severe at the end of a workday and make it difficult for her to perform routine tasks such as opening doors or participate in leisure activities such as biking. Her symptoms have also forced her to reduce the number of days she works per week, as the discomfort eventually prevents her from properly performing her job. In order to treat her RSI symptoms, our interviewee mentioned using wrist support braces similar to the one seen in Fig. 1. While the wrist braces reduced her discomfort while away from work, they failed to prevent or mitigate RSI symptoms during work. In addition, the stiffness of the wrist brace greatly limited her dexterity and impeded her productivity. She also visited an occupational doctor, a chiropractor, and an acupuncturist, but found limited success from all their treatments.

A few of our interviewee's co-workers, who experienced similar RSI symptoms, developed their own strain-reducing techniques, such as the use of long sticks in order to push their totes to the second conveyor belt without over-reaching. While using the stick reduced the strain experienced in our interviewee's back, it still involved strain of the shoulders and arms, indicating that the stick was a less than ideal solution. This workplace adaptation also highlights that the workplace is poorly designed for employee ergonomics. While management at the workplace has tried to address the employees' concerns about RSI and has implemented policies such as rotating employee workstations, these policies have ultimately been unsuccessful in mitigating RSI. However, the ability of workers to set their own working pace does help in prevent the acceleration of RSI development, indicating that a reduction of muscle load and frequency can reduce RSI symptoms.

The most critical needs extracted from our interview are summarized in Table 1. The primary pain point in our interviewee's occupational duties pertains to the strain caused by having to repeatedly reach for and lift heavy totes during work. This pain point is interpreted as a need to have fewer high load and high

TABLE I: Critical User-Need Chart

Customer Statement	Interpreted Need
I dislike the pain and discomfort while working (wrist, elbow, shoulder) due to repeated reaching and lifting actions	Fewer high-load and high-repetition actions are necessary in order to complete the work responsibilities
I dislike that supportive wrist braces get in the way at work	The remedy for RSI does not interfere with productivity at work
I dislike how far I have to reach to grab the totes off the conveyor belt	The conveyor belts can be accessed without having to excessively reach over the workstation
I dislike having to stand for the full day	Work can be completed for at least 6 hours in a workday while seated at the workstation
I dislike how management doesn't try and update the floor-plan or equipment to make it easier on my arms	The workstation and the equipment used to perform the job are set up more ergonomically

repetition actions while working. Similarly, there is also a need to update the equipment and workstation layout for improved ergonomics. Unfortunately, due to the space available, significantly changing the floor plan would be difficult, cost-prohibitive, and disruptive to business productivity. Together, these critical needs support the idea that the most impactful solution space for our interviewee would revolve around reducing the frequency and load of repetitive occupational tasks, as well as improving the ergonomics of interacting with the work-space.

Equipment to reduce the load of simple repetitive occupational tasks (such as the tasks described by our interviewee) would be relatively quick and inexpensive to develop, relative to the cost of exoskeleton and industrial robot systems. Minimizing the solution's upfront cost and disruption to productivity is crucial its commercial viability. Additionally, it should be adaptable to similar, repetitive, manual tasks in other industries. If executed correctly, this solution can fill a need in the space where full systems of industrial robots are too costly, but lost workdays and worker turnover due to RSI are detrimental to productivity.

III. Methods

Fig. 3 shows an overview of our solution: the Movable, Extendable, and Retractable Arms (MERA). This system is a middle ground: it is an extension of the worker's arms like a wearable exoskeleton, but it is also situated in the workplace like an industrial robot. Fig. 5 in Appendix A shows a detailed view of the intake and extending carriage mechanisms of MERA. The intake mechanism is responsible for picking up the totes and can be relocated spatially by the carriage, which is extended and retracted by a pulley system (see Appendix A). Using the control system, the worker is able to use MERA to pick up and drop totes at the workstation or conveyor belts (see Fig. 4). A joystick is placed behind the user's computer mouse for easy access, and MERA can function either as a standalone (i.e. joystick only) or computer-controlled device. Pushing or pulling the joystick controls carriage extension and retraction in manual control mode. The joystick thumb button powers the intake on and off, while 3 buttons on the base of the joystick allow for recording of user inputs and replay of user inputs profiles 1 (tote retrieval) and 2 (tote return), respectively.

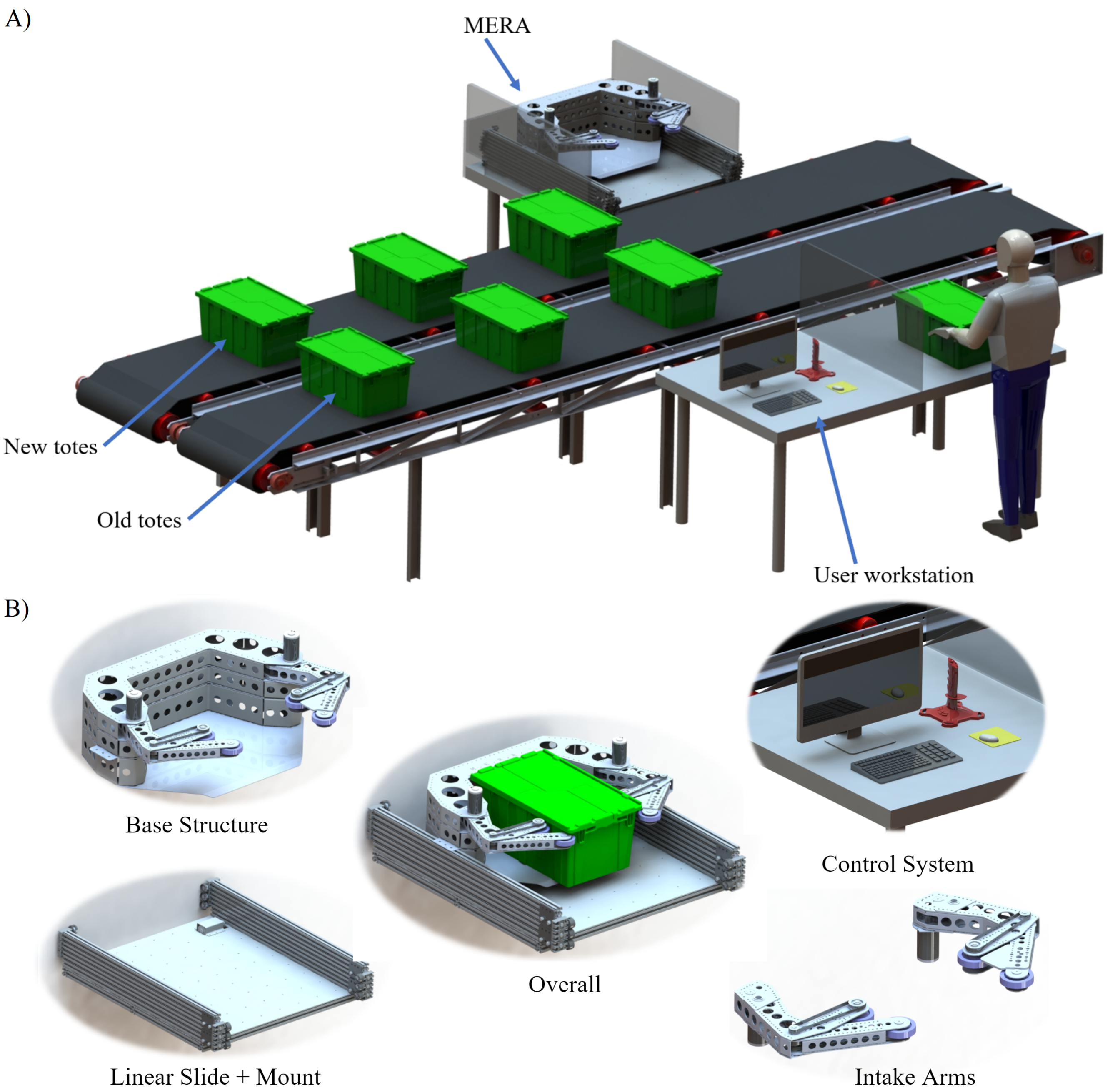

Fig. 3: A) Overview of MERA; B) MERA subsystems [13]–[17]

The intake mechanism consists of two arms, one on either side of the tote. Each arm has two high-grip rubber wheels, which grab the totes and pull them onto the plate that sits at the bottom of the intake. One of the wheels is mounted to a fixed arm, while the other is mounted on a suspended arm that can pivot. The suspended arm is needed in order to accommodate for misaligned totes on the conveyor belt. Two wheels are necessary on each arm to ensure that the totes are securely pulled in and are ejected perpendicular to the user. The wheels on each arm are controlled by one motor on each arm. Another pair of motors mounted on the intake controls the distance between the arms, allowing the intake to accommodate different sized totes. In order to ensure constant traction is applied to the totes, the arms are spring-loaded and apply a constant normal force on the tote. The carriage that the intake sits on is powered by two motors underneath the intake mechanism. A piece of elastic tubing is used to retract the carriage back to its original position (see Fig. 7 in Appendix A).

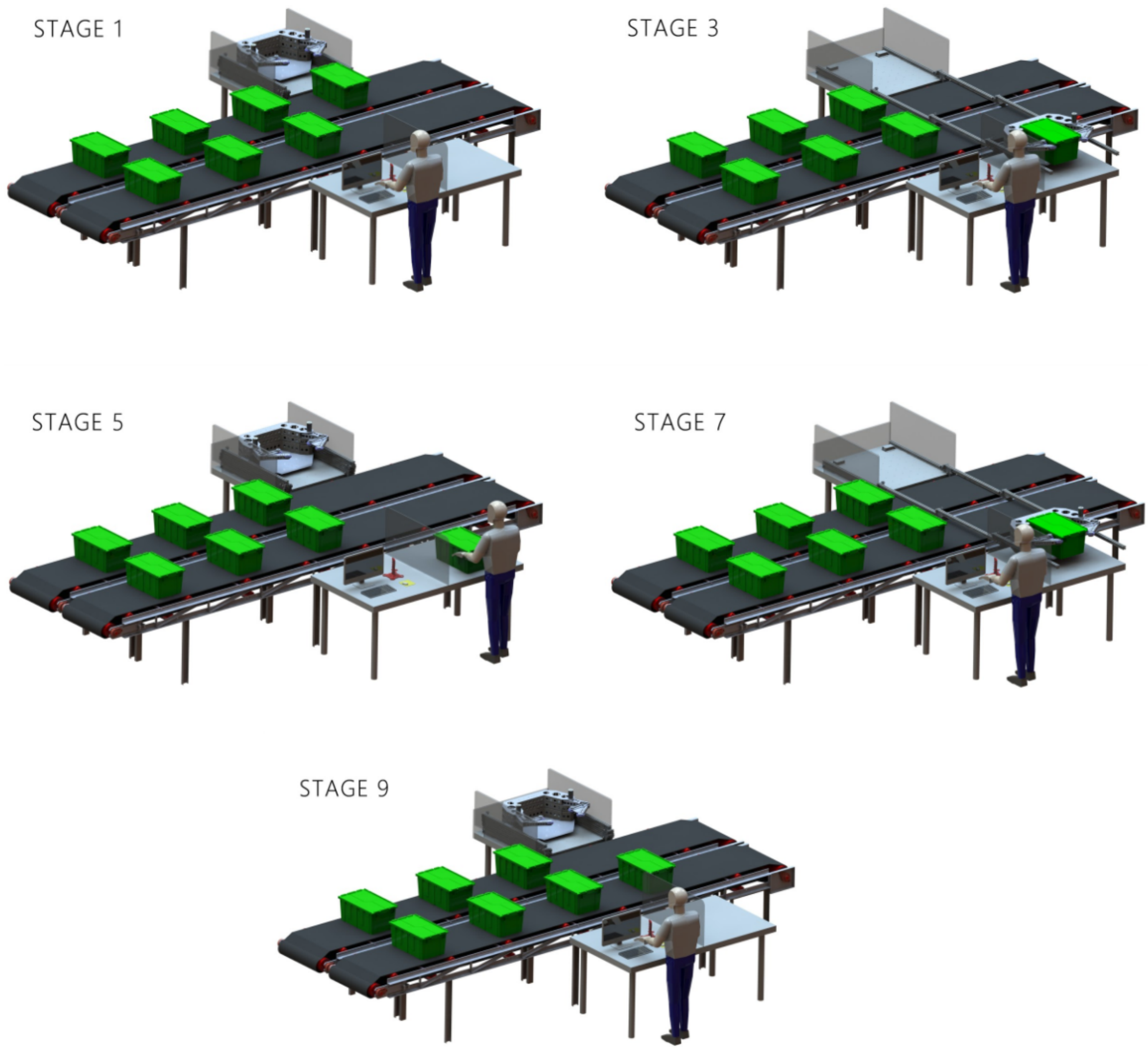

Fig. 4: Five of the nine total stages of MERA. MERA works as follows: (1) initial position; (2) intake tote at conveyor 1; (3) deliver tote to user; (4) arm retracts; (5) user inspects the tote; (6) user inputs tote information at the computer; (7) intake the tote at the desk; (8) deliver the tote at conveyor 2; (9) arm retracts to original position

To validate the effectiveness of MERA in reducing the incidence of RSI, we propose the following study. Our study would first seek to partner with a chain of pharmacies with similar working conditions to observe a population of at least 100 pharmacists. One quarter of these subjects would be part of the control group, continuing their normal workflow, while the remaining subjects would be split equally into 3 experimental groups that spend one-third, two-thirds, or all of their workday utilizing MERA. To simplify management of workflow and to maintain a sense of fairness between colleagues, each workplace will only contain one type of subject group. The study would take place over the course of one year. The first month would consist of logging weekly activities and symptoms without MERA to establish a per-subject baseline. The remainder of the year would consist of division into the control and experimental groups, while continuing the logging procedure. The collected data would allow the scientific community to examine for the underlying motions and repetitions behind RSI. From here, researchers would determine the potential relationships between partial and full removal of straining motions and loads and the progression or regression of RSI.

The study is centered around worker self-logging of weekly occupational activities (e.g. reaching and lifting) and RSI symptoms. Prior to the beginning of the study, a brief orientation will be conducted to train subjects on a standardized format for logging activities and symptoms. Specifically, subjects are provided with notebooks to document weekly how many times they perform each defined action, whether these actions were triggering or intensifying symptoms in a particular part of the body (e.g. shoulder or hand), and how intense (on a scale of 1-10) their RSI symptoms are for each body part. For experimental subjects, the orientation would include training on how to set up and safely operate MERA. Finally, at the conclusion of the study, a meeting will be held to debrief subjects and establish lines of communication for sharing of study results. The expected outcome of the study is that there will be a non-linear relationship between proportion of time utilizing MERA and incidence and exacerbation of RSI. It is expected that the experimental group using MERA for full workdays will see, by far, the most improvement, whereas the group using MERA for a third of the workday would only see marginal improvements.

IV. Intellectual Merit

The MERA system and its effectiveness can be expanded to be observationally studied in workplace environments involving high-repetition and high-strain, but simple, manual tasks. In particular, we hope that the system will allow researchers to extract information about how time spent performing repetitive tasks contributes to RSI risk and severity. It will also allow researchers to understand whether there is a linear relationship between the number of repetitive motions and the incidence of RSI, or if there exist thresholds under which injury is rare. Understanding these links between repetitive actions and RSI can then assist in the creation of more well-defined guidelines for preventing injury. For example, with sufficient data collected across different occupations, models can be built to predict how many repetitions of a motion at a given load can be performed (per day or week) without significantly elevating the risk of developing or exacerbating RSI.

V. Broader Impact

MERA fills the gap in workplaces where human participation is still necessary, but where the tasks are simple enough to be fulfilled with inexpensive equipment. Considering the pervasive nature of work-related RSI in many of these workplaces, MERA can have a broad impact on workforces at high risk of occupational RSI. Savings from an increase in productivity and mitigation of lost workdays provide a long-term financial incentive to provide workers with MERA. By aligning business and worker interests, MERA can greatly reduce the incidence of occupational RSI. The broader public, many of whom are connected to those with occupational RSI, would also be positively impacted by MERA. It would improve overall quality of life by reducing the shared burden of treating and living with the symptoms of RSI. We hope to license the system to manufacturers to recover research costs and regulate MERA pricing for maximized societal benefit.

References

[1] G. Schultz, K. Mostert, and I. Rothmann, “Repetitive strain injury among south african employees: The relationship with burnout and work engagement,” *International Journal of Industrial Ergonomics*, vol. 42, no. 5, pp. 449–456, 2012.

[2] M. Van Tulder, A. Malmivaara, and B. Koes, “Repetitive strain injury,” *The Lancet*, vol. 369, no. 9575, pp. 1815–1822, 2007.

[3] C. R. Ratzlaff, J. H. Gillies, and M. Koehoorn, “Work-related repetitive strain injury and leisure-time physical activity,” *Arthritis Care & Research*, vol. 57, no. 3, pp. 495–500, 2007.

[4] K. Walker-Bone and C. Cooper, “Hard work never hurt anyone: or did it? a review of occupational associations with soft tissue musculoskeletal disorders of the neck and upper limb,” *Annals of the rheumatic diseases*, vol. 64, no. 10, pp. 1391–1396, 2005.

[5] H. S. Konijnenberg, N. S. De Wilde, A. A. Gerritsen, M. W. Van Tulder, and H. C. de Vet, "Conservative treatment for repetitive strain injury," *Scandinavian journal of work, environment & health*, pp. 299–310, 2001.
[6] M. J. Page, N. Massy-Westropp, D. O'Connor, and V. Pitt, "Splinting for carpal tunnel syndrome," *Cochrane Database of Systematic Reviews*, no. 7, 2012.
[7] "Orthoses and carpal tunnel syndrome: Conservative treatment of cts," https://www.orfit.com/blog/orthoses-and-carpal-tunnel-syndrome/, accessed: 2021-04-11.
[8] R. J. Verdugo, R. A. Salinas, J. L. Castillo, and G. Cea, "Surgical versus non-surgical treatment for carpal tunnel syndrome," *Cochrane Database of Systematic Reviews*, no. 4, 2008.
[9] A. E. Lincoln, J. S. Vernick, S. Ogaitis, G. S. Smith, C. S. Mitchell, and J. Agnew, "Interventions for the primary prevention of work-related carpal tunnel syndrome," *American Journal of Preventive Medicine*, vol. 18, no. 4, pp. 37–50, 2000.
[10] M. P. De Looze, T. Bosch, F. Krause, K. S. Stadler, and L. W. O'Sullivan, "Exoskeletons for industrial application and their potential effects on physical work load," *Ergonomics*, vol. 59, no. 5, pp. 671–681, 2016.
[11] S. Kim, A. Moore, D. Srinivasan, A. Akanmu, A. Barr, C. Harris-Adamson, D. M. Rempel, and M. A. Nussbaum, "Potential of exoskeleton technologies to enhance safety, health, and performance in construction: Industry perspectives and future research directions," *IISE Transactions on Occupational Ergonomics and Human Factors*, vol. 7, no. 3-4, pp. 185–191, 2019.
[12] R. Hensel and M. Keil, "Subjective evaluation of a passive industrial exoskeleton for lower-back support: A field study in the automotive sector," *IISE Transactions on Occupational Ergonomics and Human Factors*, vol. 7, no. 3-4, pp. 213–221, 2019.
[13] A. Koscielski, "Simbotics," Dec 2019. [Online]. Available: https://grabcad.com/library/simbotics-frc-1114-2015-competition-robot-simbot-sideswipe-1
[14] D. A. Hai, "Belt conveyor," Mar 2021. [Online]. Available: https://grabcad.com/library/belt-conveyor-78
[15] J. Chang, "Computer desktop setup," Feb 2019. [Online]. Available: https://grabcad.com/library/computer-desktop-setup-apple-type-1
[16] L. S. Waran, "Operator interference 3d model," Mar 2021. [Online]. Available: https://grabcad.com/library/operator-interference-3d-model-1
[17] H. Utebay, "Joystick," Sep 2020. [Online]. Available: https://grabcad.com/library/joystick-75

APPENDIX A
INVESTIGATIONAL DEVICE DETAILS

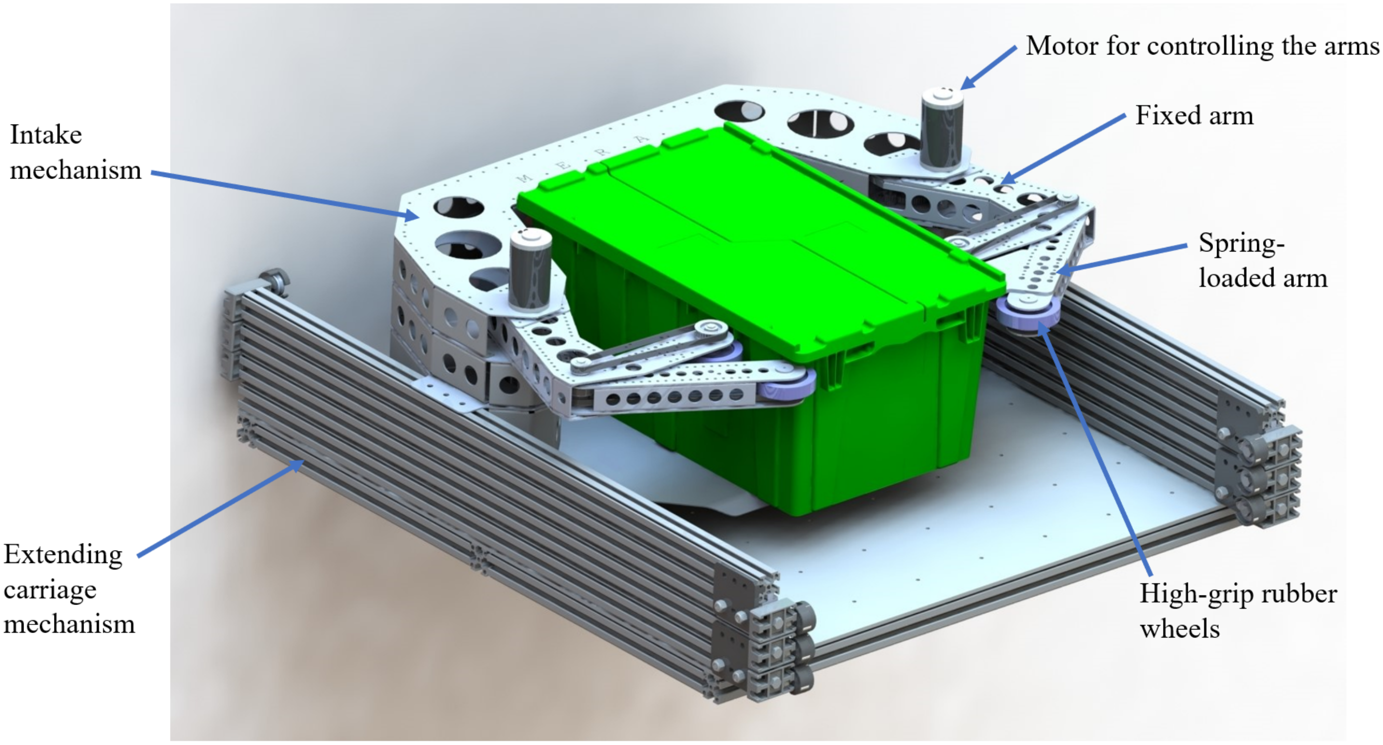

Fig. 5: Overview of the MERA intake [13]

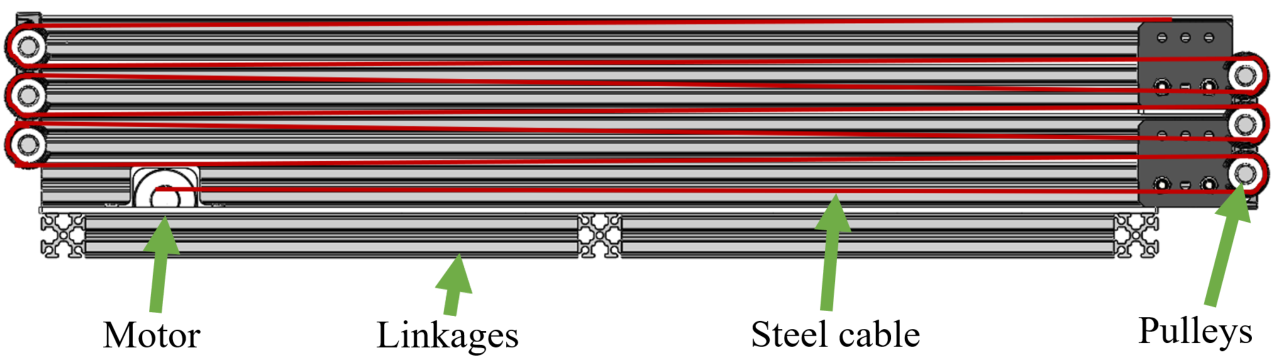

Fig. 6: Diagram of extension mechanism - the motor shortens the available cable length, pulling the pulleys together and extending the carriage.

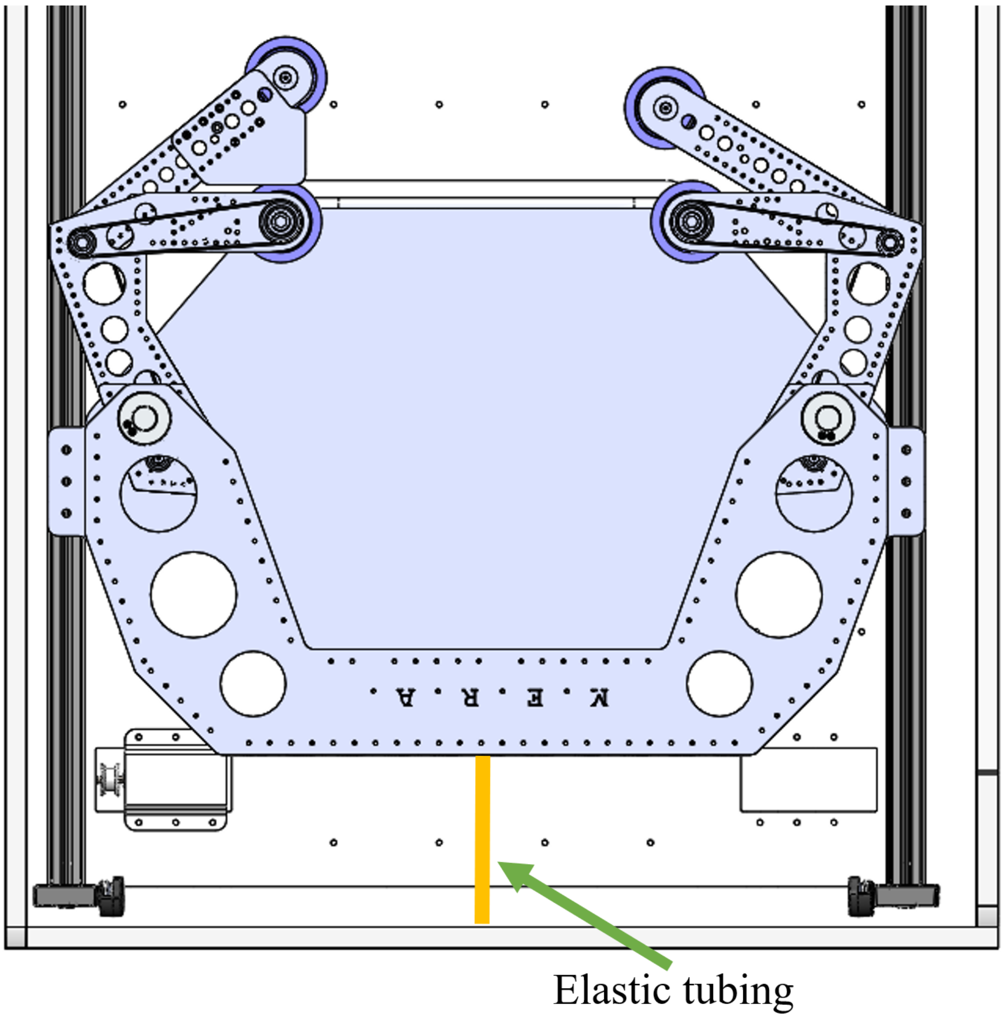

Fig. 7: Diagram of elastic tubing placement for carriage retraction - the tubing provides a force to retract the carriage from an extended state. [13]