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Editorial

# Soft Robotic Gloves Offer Great Promise in Preventing Work Related Musculoskeletal Disorders

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## Background

Musculoskeletal disorders (MSDs) are the most common workplace injury, with 327,650 occurring in the U.S. in 2019 according to the U.S. Department of Labor, Occupational Safety, and Health Administration (OSHA) [1]. The Bureau of Labor Statistics of the Department of Labor defines MSDs as musculoskeletal system and connective tissue diseases and disorders when the activity or exposure leading to the onset of symptoms is bodily movement (i.e. bending, reaching, twisting, crawling, climbing), overexertion, or repetitive motion. MSDs do not include disorders caused by incidents of slips, trips, falls, or similar mishaps. Examples of MSDs include, but are not limited to: sprains, strains, and tears, back pain, and carpal tunnel syndrome [2]. MSDs carry a high price tag for employers. Included in this steep cost are tangibles such as absenteeism and lost productivity. Additionally, there are increased health care, disability, and workers' compensation costs. This price tag is higher than the average nonfatal injury or illness [3].

Work-related musculoskeletal disorders (WMSDs) are conditions within the work environment and as a result of the performance of work in this environment, contribute significantly to the condition. This may also include a worsening or persistence of symptoms due to work conditions [4]. Types of work conditions that may lead to WMSDs include, but not exclusive of, repetitive lifting of heavy objects, exposure to whole body vibration daily, repetitive or prolonged overhead work, work with the neck in chronic forward flexed posture, or the performance of repetitive forceful tasks. It has been demonstrated that there is strong evidence for a significant correlation between work conditions and MSDs of the neck, back, and upper extremity [4].

With regards to types of work conditions that cause WMSDs, repetitive lifting of heavy objects involves multiple joints. The first joints to set the stage for the lifting are the fingers and wrists. It is at this commencement of the lifting or grasping of an object that this paper will focus on.

### Current research

Scant research has been done in the past decade on soft robotic gloves as a means of strength augmentation. It is strength augmentation that plays a key role in preventing WMSDs.

In a targeted Google Scholar search of over 400 articles, only seven were found to meet the search criteria of soft robotic gloves for use in industry or simulated industrial setting. Despite this scarcity of research, there is strength in the proposals of these articles with regards to the appropriateness of the use of soft robotic gloves to help reduce or prevent WMSDs. However, no research was found that utilized soft robotic gloves in industry on a large scale.

This paucity in research should not dampen the enthusiasm for these gloves in the fight against WMSDs. What has been done has been very promising.

Alicea R., *et al*. (2021), discovered that their nimble glove was easy to put on and off and precipitated enough force for hand closure to assist with activities of daily living. Furthermore, they offered a preliminary case study in which an individual with an incomplete spinal cord injury (C7) using their glove, was able to realize a 50% performance improvement in a standard Box and Block test [5]. Also revealed by Alicea R., *et al*. (2021), was the use of the glove by two healthy individuals led to an overall decline of 22.8% of the activity of the flexor digitorum superficialis on EMG testing [5].

Nine workers at Honda of Canada Manufacturing utilized a grasp assist device (dynamic hand-wrist orthosis) and experienced a reduction in 18.5% for %MVE (percentage maximal reference contraction) in comparison to grasping the same tool without the device. The probability was an impressive $p < 0.01$ [6]. Granted the device developed and used in this thesis study was not a glove, yet it still exhibits the grasp augmentation a soft robotic glove can provide. In all actuality, this grasp assist device has actuators similar to soft robotic gloves seen in other research. Furthermore, Loewen demonstrates that using the grasp assist device reduces the Revised Strain Index by a mean of 13% compared to no device [6].

Robo-Glove, a novel soft robotic glove, developed jointly by General Motors (GM) and the National Aeronautics and Space Administration (NASA), has claims of reducing the force needed by a factory assembly operator to hold a tool to perform the required task from 15 to 20 lbs. of force to only 5 to 10 lbs. of force [7].

Villoslada., *et al*. (2018) takes a similar approach in that they developed the first controlled (shape memory alloy) SMA-actuated hand exoskeleton called Hand Exo-Muscular System (HEMS). While designed to be embedded into the spacesuit glove, it promises to minimize stiffness while reducing the bulkiness of the glove. The hope is to drastically decrease the force needed to move the digits when utilizing an EVA (extravehicular activity) glove [8]. This in turn should make EVA tasks less demanding on the hands and avoid other difficulties that plague the hand during EVA missions. Other investigators have documented when using EVA gloves, the astronaut's grip strength was decreased up to 50% of the force exerted with bare hands [9,10]. Villoslada., *et al*. (2018) demonstrated that the HEMS actuation system testing actually had the capability of enabling at least 50% of the force needed to exceed the opposing forces of the EVA glove [8].

The Bioservo Ironhand soft exoskeleton glove is another example of a strength augmentation device. It is licensed and commercialized by Bioservo Technologies, with its parent glove being the Robo-Glove (See above). It contains a processor that is embedded in the glove that gauges the required force for the task. Once this force is determined, the artificial tendons within the glove implement the extra force needed, reducing the force on the operator's tendons and muscles [11,12].

The Myoglove is a soft wearable glove containing the user's motion intent detection. This detection is characterized by machine learning approaches recorded in a closed-loop control. The initial use of this glove is for task-oriented restorative training. Its design can also enable it to function as strength augmentation [13].

Chiaradia., *et al*. (2021) designed and implemented a soft wrist exosuit with an ergonomically designed reinforced glove that demonstrated isometric muscular activity reduction that was statistically significant for the following forearm muscles: flexor carpi radialis and ulnaris, and the extensor carpi ulnaris. These measurements were done with healthy subjects holding loads up to 3 kg [14].

## Great promise

The aforementioned research studies demonstrate these various gloves' abilities to augment the existing grip strength, whether isometric or isotonic muscle contractions. One such glove detects the user's motion intent detection as characterized by machine learning approaches that are recorded in a closed-loop control. Another glove contains a processor that is embedded in the glove that gauges the required force for the task. So, we see that utilizing advanced information processing, including machine learning, can offer more than just helping the worker lift more with less grip force. There is a precision in the grip force which can be very specific for a required job task. Thus, the great promise of reducing WMSDs.

So, what do these actuated gloves really do to reduce WMSDs? Stress relief, to put it in general terms. The main activity that leads to WMSDs is repetitive stress placed on contractile and non-contractile structures. These structures include tendons, ligaments, muscles, fascia, nerves, bursae, articular cartilage, and blood vessels. Examples of the more common WMSDs include: carpal tunnel syndrome (nerve and tendons), rotator cuff tendinitis (bursa may be involved), lateral epicondylitis (tendon and bursa), DeQuervain's (tendon and sheath), postural muscle strains (most common is low back strain), and degenerative joint disease (lumbar spine, hip, shoulder, and knee being the most common).

These gloves have a great potential to reduce these (and other) WMSDs by reducing the force requirements on the body at the beginning of the lifting or grasping activity; hand contact with an object. Of course, proper body mechanics is essential and "getting a grip" is more than just a saying. The input from the proprioceptors in the wrist and hand joints is crucial to a safe lift, but also to set the stage for readiness in the regional tissues to respond to the ensuing lift or grasp. It is in these first milliseconds of a lift or grasp in which there is inadequate strength due to weakness or poor proprioceptive input that many injuries occur. The other joints above in the mechanical chain respond more rapidly and with higher muscular force output than usual, with their various tissue matrices undergoing stresses beyond their structural capabilities. This is the moment of "failure"; the genesis of a WMSD.

This one scenario in the making of a WMSD demonstrates this great promise that soft robotic gloves can provide. Of course, more research is needed and the lab should be on the manufacturing floor. Now is the time (or should I say it is "at hand") for industrial testing, not with a few employees doing simulated tasks, rather in line testing with the rigors of academia laboratory testing. Don't the millions of workers worldwide deserve this?

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