# UW Adapted Fitness: Grip Strength Improvement Mechanism

*Preliminary Report*

*BME 200/300*


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# Abstract

Grip strength is an important biomarker that predicts muscle strength and overall physical health. With a large percentage of the population 65 and older suffering from clinically weak grip strength, mechanisms must be implemented to improve grip strength. Existing grip strength devices fasten the user to the gripped object and require assistance to put on. The client, Dr. Kecia Doyle, has requested the fabrication of a device that assists in gripping and hand extension, as well as improves grip strength over time. The device will be used by a hemiplegic stroke survivor, for both everyday activities and exercising. The gripping mechanism must be used without outside assistance and must be easily disinfected. The final design consists of a silicone exoskeleton that encompasses the exterior hand and fingers. A thread and motor system, running along the fingers, forces the hand into either gripping or releasing motions. With the palm exposed, the device can be put on without external assistance and the silicone material exterior can be disinfected. Once the device is fabricated, grip strength will be measured using a hand dynamometer and tests will determine if the device is usable with only the user's dominant hand.

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## *Introduction*

Grip strength, the power generated by the muscles of the hand and forearm, is a biomarker for overall health and mortality. Specifically, grip strength is a reliable predictor of muscle function, bone mineral density, and malnutrition within an aging population [1]. The cutoff for weak grip strength for men is under 28.5 kg and 18.5 kg for women. Within the aged 65 and older population, 52.9% of males and 69% of females have weak grip strength [2]. There is a significant correlation between weak grip strength and walking limitations, as older individuals with grip strength below the threshold have difficulty walking over 0.5 km or climbing stairs. Studies also found that a sampled population of individuals with hip-fractures had clinically weak grip strength [3]. The correlation between weak grip strength and overall quality of life stresses the importance of improving grip strength within an elderly population.

Grip strength can be improved through forearm strengthening exercises and through the use of assisting devices. Competing designs include the General Purpose Gripping Aid, manufactured by the company Active Hands. The glove-like design forces the hand into a fist shape, allowing for gripping of various sized items [4]. The device fastens the user's palm to the gripped item, which prevents the quick release of the object in an emergency situation. Similarly, the Gripping System, Apparatus, and Methods Patent, US8192296B2, describes a two-member mechanism that provides users with weakened hand strength a tighter grip around everyday objects. The mechanism consists of a mating glove that fastens to compatible material on the object to be gripped [5]. The device is fabricated from hook-and-loop fastener material that mates with retrofit tape wrapped around the graspable surface.The device must be fastened to both the user's hand and the gripped object, which might require assistance to use. The Exo Glove, developed by Kyujin Cho at Seoul National University, is a wearable robotic glove that allows paralyzed users to grasp and pinch objects. The device consists of a wearable three-finger glove and a tendon actuation system that is motor controlled, providing a pinch force of 20N and a grasp force of 40N [6]. However, the Exo Glove is currently unavailable for consumer use.

The prevalence of weak grip strength and the limited availability of grip-improvement devices necessitates the fabrication of a mechanism that improves grip and release strength. The device should stimulate the hand and forearm muscles to improve grip strength overtime, as well as assist the user in gripping and releasing objects. The fabrication of a grip-improvement mechanism will contribute to the overall health and wellbeing of aging individuals.

## *Background*

Grip strength is measured using a hand dynamometer to determine the amount of force generated by curling the fingers to the palm. However, it should be noted that grip strength can be divided into a pinching grip (force from fingers to thumb), a crushing grip (force from fingers to palm), and supporting strength (force required to carry an object for a length of time) [7]. Weak grip strength is defined as under 28.5 kg and 18.5 kg for men and women respectively [2]. It is important to note the muscles involved in creating this force: flexors in the hand and forearm create gripping force, while the extensors of the forearm help stabilize the wrist. Therefore stress induced by exercising the flexors in the hand and forearm is the best method for growing grip strength [7]. Weak grip strength is especially prevalent in stroke survivors, 67% are unable to use their hand, four years after the event [8]. Not only is grip important for daily tasks but there is a correlation between a weak grip and a variety of other ailments: increased mortality, cardiovascular disease, diabetes, and chronic kidney disease [9].

The client, a member of the University of Wisconsin-Madison Adaptive Fitness program, is a retired mechanical engineer who has previously attempted to build similar devices. The client is hemiplegic on their left side, suffering from a stroke 6 years ago that weakened their left hand. The client wants a glove that they can operate independently, aiding them in daily activities and fitness. Ultimately, the most important aspect of this device is to improve grip strength while providing help with flexion and extension of the hand. It is also vital that the glove can be attached and detached without outside assistance and provide biofeedback to track client growth. The device must provide a consistent grip to objects of varying sizes similar to how the unaffected hand functions. Additionally, the device will feature a rapid hand release for emergencies to ensure the user's safety. Skin-safe materials will be used to protect the client and the dimensions of the device will be fit specifically to the hand of the client.

To fabricate the prototype the team will primarily focus research on biomaterials that are easily disinfected and sanitized, following ASTM Standard E1837-96 [10]. These materials will also need to be lightweight to provide the client with a comfortable experience while wearing the device. Furthermore, all robotic elements of the smart grip enhancement device including the curling mechanism will need to be researched and must adhere to ISO Standard 10218 [11]. When quantifying the grip strength of the glove-like mechanism, measurements will comply with ASTM Standard F2961-24 [12].

## *Preliminary Designs*

**Design 1: Skeleton Glove**

The first design uses an outline of the joints in the hand and is designed with physical activity (predominantly weightlifting) in mind. Using a system of electronics located in the wrist, the silicone fingers and fingertips will be pulled by a thread connected to a motor allowing the fingers to close around whatever object the user is holding. This grip can be locked in place using a switch on the back of the hand. The fingers will be made of rigid plastic sections outlining the skeletal structure of the user's fingers allowing them to bend similarly to the typical hand: each knuckle is capable of independent movement. After the user places their hand inside the silicone layer and moves their fingers into the skeletal frame, the synthetic threads connected to the motors will rest beneath the fingers; awaiting the initial pressure from the user to begin contraction. This motor would be charged with a reusable battery. This design emphasizes maintaining a natural finger structure without needing a fully covered glove.

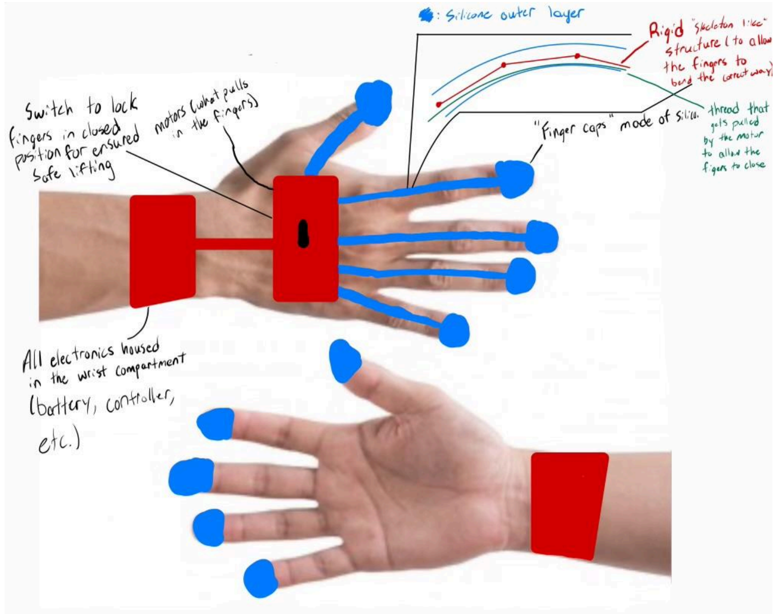


**Figure 1:** Sketch of the skeleton glove design.

**Design 2: Palm Glove**

This design uses a motor system with wire cables located on the palm side of the hand to assist the user in closing their hand. The palm would be entirely covered in an athletic, breathable nylon material and have small grippy circles similar to the ones used in socks for maintaining balance. To fasten the device to the user there would be several velcro strips placed near the knuckles and along the wrist that could be easily fastened using the opposite hand. On the inside of the material, there will be sensors placed at each fingertip to determine if the user is attempting to grip or release their hand. While gripping, the motor in the wrist will activate contracting the cables and causing the finger to curl. When releasing, the cables will loosen; slowly helping the user extend their fingers once again. This design emphasizes maintaining a secure grip with maximal discreteness.

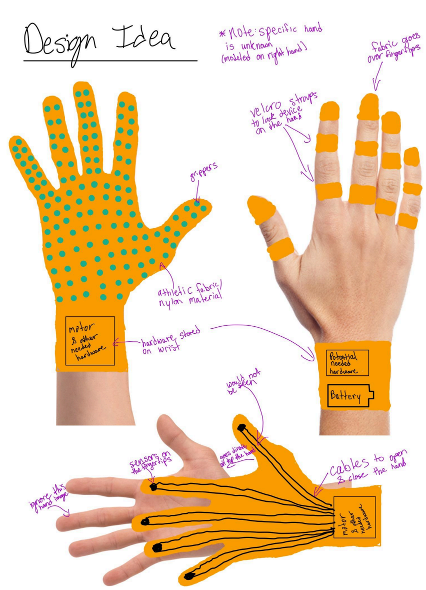

**Figure 2:** Sketch of the palm glove design.

**Design 3: Electromagnetic Grip Assistor**

In this design, electromagnets would be embedded in the glove at key locations in the finger joints and palm. When activated, the magnets could either attract (to assist gripping by pulling fingers toward the palm) or repel (to resist or assist in opening the hand) depending on the mode. The design would also involve EMG sensors to monitor muscle activity and control the strength and timing of the electromagnetic forces. This adaptive system would provide varying levels of assistance depending on the user's needs. This device would have the electronics located on the wrist with a simple switch for determining if the user is gripping or releasing. This design can be slipped on or off using a zipper to attach at the wrist and would be powered via rechargeable battery. This design emphasizes both gripping and retracing of the fingers and user feedback.

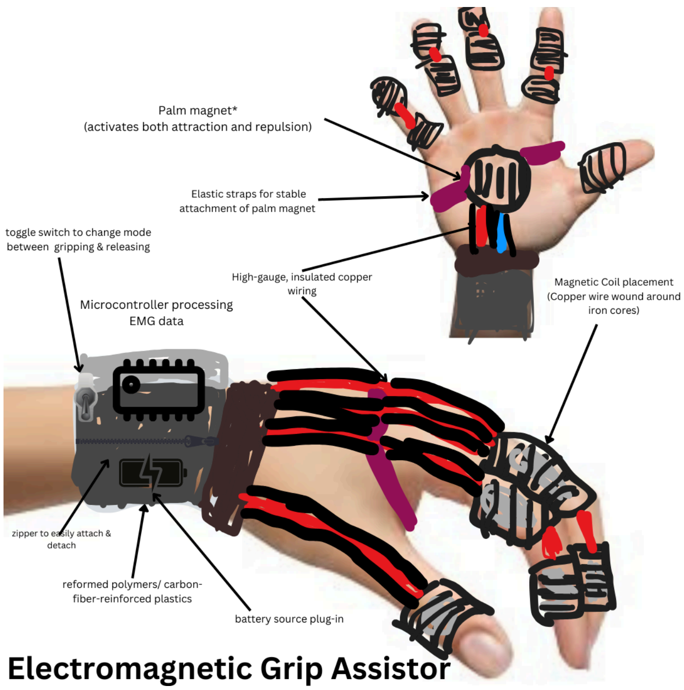


**Figure 3:** Sketch of the electromagnetic grip assistor design.

## *Preliminary Design Evaluation*

| Criteria (Weight) | Design 1: Skeleton Glove | | Design 2: Palm Glove | | Design 3: Electromagnetic Grip Assistor | |
|---|---|---|---|---|---|---|
| **Effectiveness (25)** | 4/5 | 20 | 3/5 | 15 | 4/5 | 20 |
| **Safety (20)** | 5/5 | 20 | 5/5 | 20 | 3/5 | 12 |
| **Variety of Use (20)** | 4/5 | 16 | 2/5 | 8 | 4/5 | 16 |
| **Unassisted Use (15)** | 4/5 | 12 | 5/5 | 15 | 3/5 | 9 |
| **Sterilizability (10)** | 5/5 | 10 | 3/5 | 6 | 3/5 | 6 |
| **Cost (5)** | 4/5 | 4 | 4/5 | 4 | 2/5 | 2 |
| **Discreteness (5)** | 3/5 | 3 | 5/5 | 5 | 2/5 | 2 |
| **Total (100)** | 85 | | 73 | | 67 | |

**Effectiveness (25):**

The purpose of the device is to improve the client's grip strength. Effectiveness refers to how successful the device will be in improving grip strength, considering the device's material, design, and biosensor feedback accuracy.

Both skeleton glove and electromagnetic grip assistor have scored 4/5 for effectiveness because of their overall satisfactory ability to deliver the main objective for the client to improve grip strength over time. The silicone fingers encompassing around the client's fingers will allow flexible movements of grip in a secured manner. The attractiveness between the magnets of the fingers and palm will also cause gripping in a controlled way. Through consistent training with both designs equipped and availability of live biofeedback makes them more suitable and desirable for the client for continuous usage and further improvement. The two designs also provide enough security and stability for the client to easily grip without much disturbance or disorientation to effectively achieve the objective. On the other hand, the palm glove scored 3/5 because of its potential risk involved in damage of the design while gripping in motion because of its heavily one-sided configuration of the device's material coverage on the entire palm.

**Safety (20):**

The device will directly interact with the patient, therefore, it must be safe to use. Safety considers the placement and storage of all electronic elements of the device and how easily the device components can be released from the grip in urgent, unexpected situations.

The skeleton glove scored 5 out of 5 due to its dedicated focus on safety. This design ensures that all electronic components are located in the wrist, which minimizes exposure to sensitive areas of the hand. The skeletal framework is also designed to maintain a natural hand structure, and the grip can be easily released via a switch on the back of hand that offers an option to quickly release in urgent situations. Palm Glove also scored

5 out of 5 with its electronics similarly stored in the wrist, durable materials and velcro fastenings that can be easily detached. This also ensures safe and fast operation of removal if needed. Electronic Glove Assistor scored 3 out of 5 by its complex addition of electromagnetic system and attachment of EMG sensors. Despite providing much adaptive system, this setup could potentially introduce hazards, such as direct interference from electromagnetism, making it slightly less safe and reliable than the simpler and more biomechanically focused designs of the other two designs.

**Variety of Use (20):**

Variety of use defines the ability of the device to adapt to the shape and size of the object that will be gripped and refers to the setting in which the device will be used. The device should allow gripping of a variety of objects in both everyday and exercise settings.

Skeleton Glove scored 4 out of 5 due to its flexible design that accommodates various motions of hand and different kinds of object shapes. The motorized thread system allows precise control over the grip, making it adaptable to objects in different dimensions which is applicable for both physical training and daily activities, with the small exception of weightlifting limiting its full versatility. Electromagnetic Glove Assistor scored 4 out of 5 too, as its electromagnetic system offers adaptive assistance for gripping objects of various scales. Furthermore, the EMG sensors allow for customization based on user needs, making it suitable for a wide range of setups for training purposes. However, its complexity makes it not the most ideal candidate for general applicability. Palm glove scored 3 out of 5, because it primarily focuses on providing grip assistance with limited flexibility. The use of wires and the focus on secure grip may reduce its functionality to adapt to objects of varying sizes especially in training setting, which makes its level of versatility significantly lower compared to other designs

**Unassisted Use (15):**

The client is a hemiplegic stroke survivor, requiring assistance for most everyday activities. The glove should give the client independence for gripping and releasing objects. The device should be simple to put on and use, requiring little external assistance.

The palm glove ranked the highest for unassisted use because the client would slip the entire hand through the electronic wrist storage, and then could strap in their fingers using their dominant hand. The act of putting this glove on could occur independently as the fingers must only lay flat to be put on. The skeleton glove would be simple for the client to put on unassisted, as the finger would be popped into the exo-skeleton, which would occur with the use of their non-paralyzed hand. The electromagnetic grip assistor would require external assistance to put on because the client's hand would have to fit into the glove, rather than the glove fitting around the hand.

**Sterilizability (10):**

The device will be used for exercising and everyday tasks, which requires the device to be easily disinfected or cleaned. Sterilizability considers how easily the device's material will be cleaned.

The skeleton glove received the highest ranking for sterilizability because it would be fabricated using silicone, which can be sanitized using disinfectant spray. None of the electronic aspects of the device would get wet during sterilization, as they are embedded in the wrist bracelet and silicone fingers. The palm glove's non-slip material could be cleaned using a machine washer, however, the electronic aspects would have to be removed prior to cleaning. All of the electronic aspects of the electromagnetic grip assistor are exposed, making sterilization of the device more difficult as it can not be sprayed with disinfectant or machine washed.

**Cost (5):**

The budget for the project is currently unknown, however, the device should be fabricated using as small of a budget as possible. The client wants the device to be available to all patients, regardless of financial situation, so the cost should remain low.

The skeleton glove received a ⅘ ranking for cost because the materials used to fabricate the glove are relatively budget friendly. The fingers and exterior of the hand would be fabricated from 3D printed silicone and the microcontroller would utilize an Arduino, which are materials readily available in the MakerSpace. The palm glove would require ordering of non-slip fabric and similar electronic elements, but would be within the budget. The electromagnetic grip assistor would be the most expensive design as magnets, iron cores, and copper wires would quickly become expensive making the glove inaccessible to lower income clients.

**Discreteness (5):**

Discreteness refers to how the device interacts with the hand. The device's appearance should be relatively inconspicuous and should not impede the client's grip strength.

The palm glove received the highest ranking for discreteness because it would be fabricated from thin non-slip material that is relatively weightless. Since the glove only encompasses the palm and fingertips, it leaves the majority of the hand exposed making it inconspicuous compared to the other designs. The skeleton glove design consists of an exo-skeleton on the exterior hand and a bracelet containing the electronic components, which could contribute to the device's weight, making it difficult for the patient to lift their paralyzed arm. The electromagnetic grip assistor is the least discrete design, as the palm magnet, iron cores, and microcontroller contribute to the design's bulkiness.

**Proposed Final Design**

The skeleton glove was ultimately chosen because the thread and motor system forces the fingers into a gripping motion and the exoskeleton exterior provides structure but it is flexible enough for finger movement. The button that locks the threads into place for gripping will ensure that there is no slipping, and will act as a safety measure for rapid release in emergency situations. The client will be able to use this design unassisted, as their wrist will be fastened to the device using an adjustable strap and will place the back of their hand and fingers into the exoskeleton mold. We plan to fabricate the device using silicone, which can be sterilized using disinfectant spray and will be relatively lightweight and non-bulky, allowing the client to easily lift the device. We have not yet received the client's hand dimensions, however, we can begin fabrication plans using the average hand dimensions of adult males: across palm (8.5-9.5 in), wrist size (7.1-8.7 in), distance from wrist to tip of middle finger (7.7-11.0 in) [13].

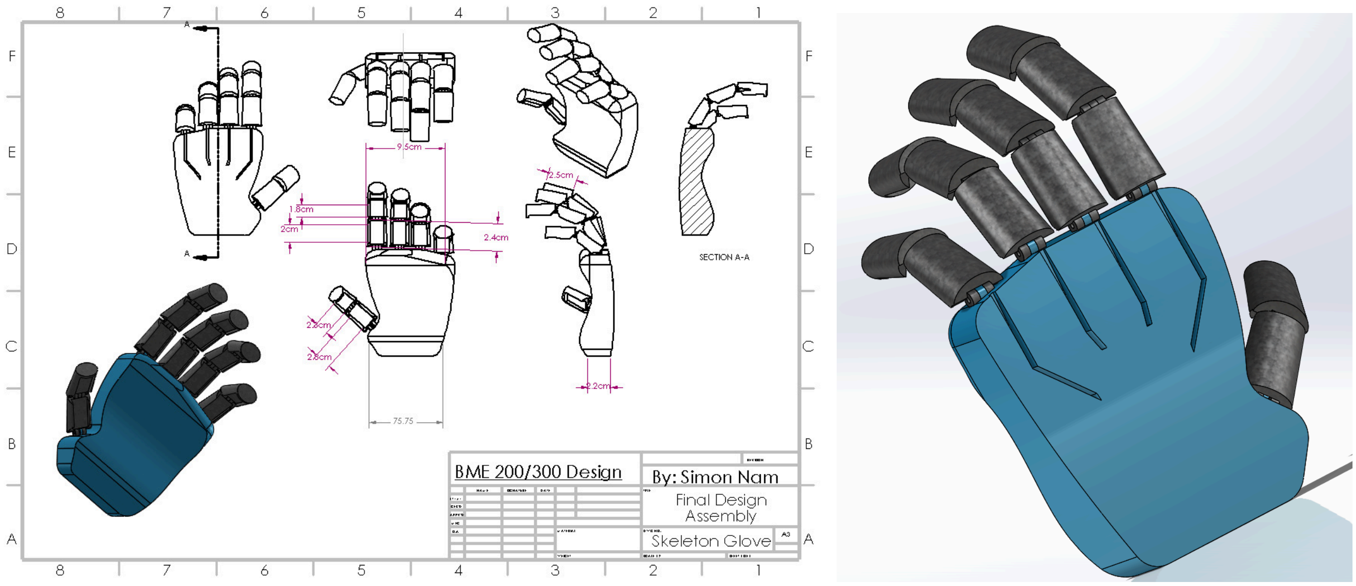


**Figure 4:** SolidWorks assembly of the final glove design.

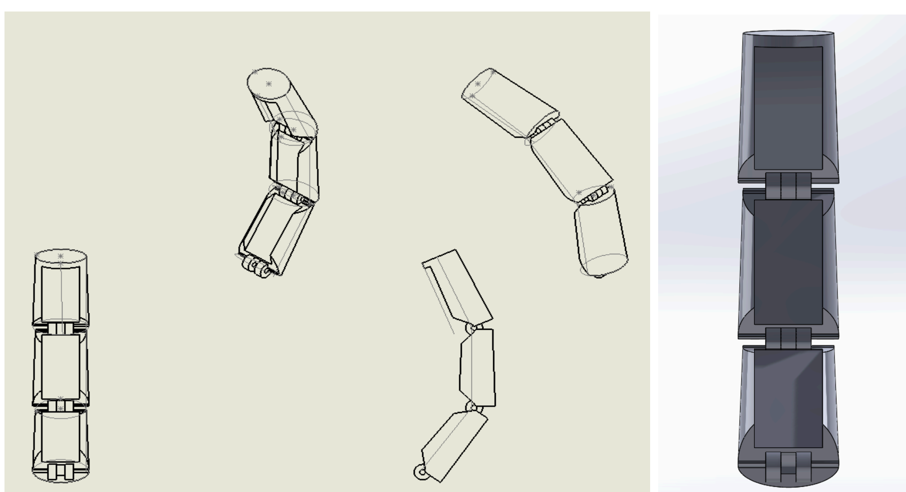

**Figure 5:** SolidWorks design of the individual fingers for the final glove design.

## *Fabrication*

### Materials

The skeleton glove will be fabricated using silicone. Silicone is a synthetic polymer containing silicon, oxygen, carbon, and hydrogen. The highly ionic silicone-oxygen bonds give silicone high thermal resistance and chemical stability. Silicone is flame resistant and has good electrical conductivity, allowing the thread and motor system to be embedded within it. The material is highly elastic and has a low glass-transition temperature, retaining its flexibility at all temperatures, allowing for a range of finger movement [14]. Silicone is highly hydrophobic and can be sterilized using disinfectant spray. It is optically transparent and lightweight, allowing for the client to lift the device during use.

**Methods**

Overall Design Block Diagram:

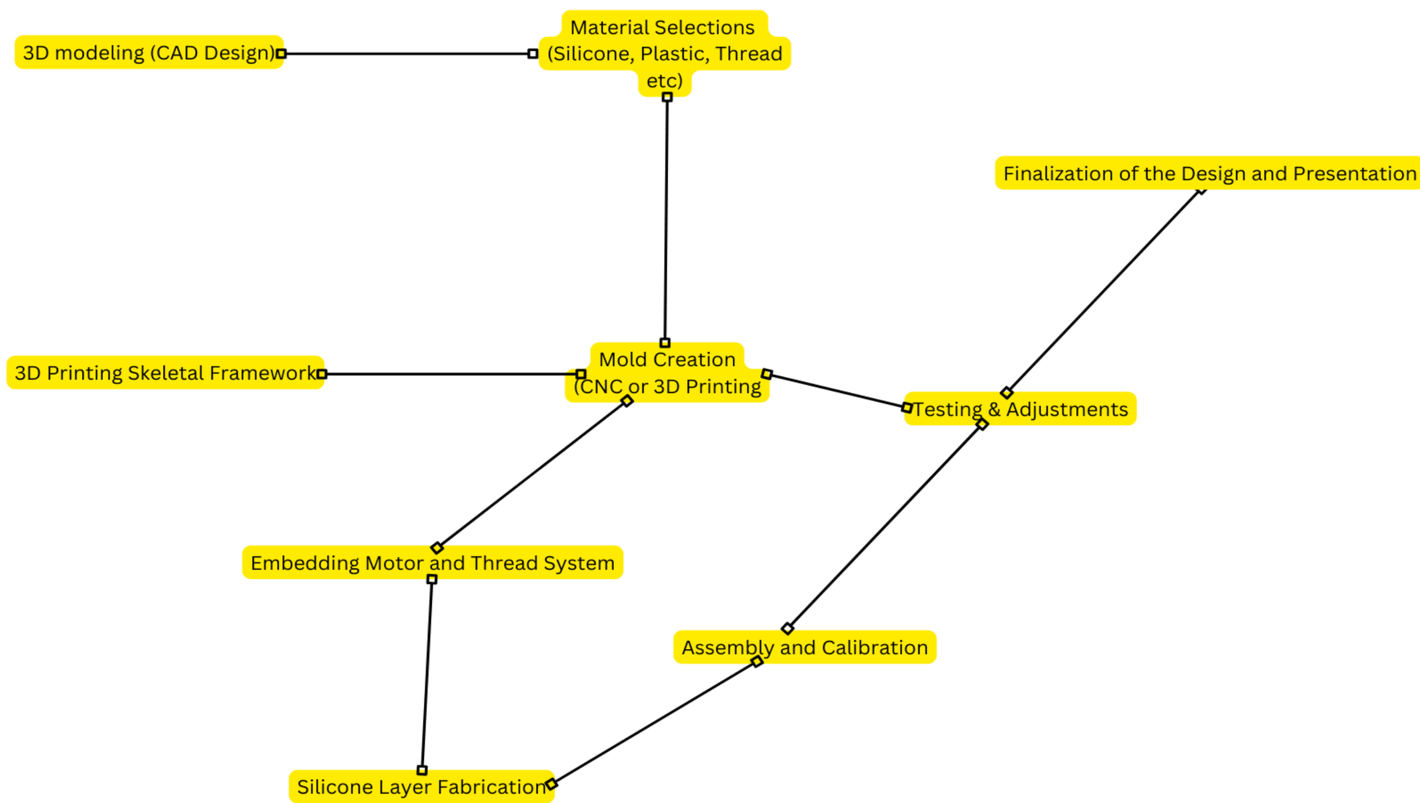


**Figure 6:** Skeleton Glove Design Block Diagram for Fabrication

Description of Fabrication for the Skeleton Glove Device:

1. Design and 3D Modeling: The detailed, finalized 3D model of the skeleton glove using CAD software(SolidWorks) will be created. The model should include individual finger segments that are customized based on the client's hand along with joints that allow independent movement. The structure will also feature channels for synthetic threads that will pull the fingers closed along with suitable compartments for the electronics, motor, and battery in the wrist section. Refer to Figure 4 and 5 for current 3D model representations of the design.
2. Material Selection and Acquisition: Appropriate scale of silicone for flexibility, durability, and strength will be chosen. The rigid plastic sections for the skeleton will be made of lightweight, durable materials such as ABS or polycarbonate in order to outline the joints and keep the glove structure secure.

Synthetic thread can be fabricated using the available materials and tools at Design Innovation Lab for connecting to the motor to ensure durability and strength under tension and compression.

3. Mold Creation: Molds for the silicone layer that will be designed according to the justified dimensions of the hand and fabricated to encompass the client's hand. This mold creation is intended to resemble a flexible skin type for the glove structure.
4. 3D Printing of Skeletal Framework: The finger segments and skeletal framework will be created using 3D printing with the selected rigid plastic material which will be determined in the later stages of fabrication. This framework needs to consider precision in the joint articulations for smooth and adaptable movements of fingers in terms of flexion and extension.
5. Embedding the Motor System and Threads: The motor will be physically attached in the wrist part of the glove. The power source which will be a rechargeable battery is securely connected and placed. The synthetic threads will be feeded through the channels within the skeletal finger sections, connecting them to the motors. Each thread must be properly tightened and be able to withstand pressure from the user's initial motion of gripping.
6. Silicone Layer Fabrication and Addition: The Silicone will be poured into the molds for the outer layer of the glove. The silicone layer must be integrated in such a way that it holds securely to the skeletal frame while allowing the client to insert their hand comfortably.
7. Assembly and Calibration: The motor system, battery, switch on the back of the hand will be assembled to ensure that the motor operates smoothly to pull the threads and assist the fingers. The locking mechanism will also be installed that allows the grip to stay locked until manually released which is designed specifically for the purpose of UW Adapted Fitness training sessions.
8. Testing and Further Modifications: After assembly, the design must be tested to check the functionality of a wide range of motion and proper grip strength. The joints should be moving independently and the motorized grip should respond and adjust accordingly to the client's motive. Any modifications to the thread tension, motor rate, or structural components can be made based on the client's feedback and testing results.
9. Final Assembly and Sealment: All the components that are modified should be securly attached and electronics should now be sealed properly within the silicone to prevent exposure to moisture or surrounding factors. The battery and motor housing should especially be compact and not hinder any movements.

## *Testing and Results*

Tests will be performed on the device to determine a few different criteria of the device. The criteria that will be tested is ability to improve grip strength over time, ease of use to put the device on, ability to perform everyday tasks, and the users overall comfort using the device. One test that will be performed is the grip strength test. In this test the client will measure their grip strength using a dynamometer, before ever using the device, and then will test their grip strength once every week (with the device off every time) in order to test the device's ability to improve the clients grip strength over time. The second test that will be performed is the ease of use to put the device on test. In this test we will have a sample of people attempting to put on the device with only their dominant hand and then rating how easy it was to put the device on on a scale of 1-10, the average will be taken to determine how easily the device can be put on the patient's hand by themselves. The third test will be the everyday task test, where the client will be observed using the glove to do everyday tasks and then graded on and will grade themself on multiple categories to determine how useful the device is at assisting in everyday tasks. The final test will be the comfort of use test. The client will be given a survey and asked to fill out a variety of questions on how comfortable they are with the device. Further testing can be conducted to assess the device's effectiveness in other aspects if needed.

## ***Conclusions***

The client requested the fabrication of a mechanism that assists the user in gripping and extending, while also improving grip strength over time. The device must contribute to the client's grip strength and should be put on independently. The device should also be easily cleaned and relatively lightweight and non-bulky. The final design consists of a silicone exoskeleton that encompasses the exterior hand and fingers. A thread and motor system, running along the fingers, forces the hand into either gripping or releasing motions. With the palm exposed, the device can be put on without external assistance and the silicone material exterior can be disinfected. This device will provide the user with independence by assisting in gripping of everyday objects and exercise equipment.

Future work will focus on finalizing the material choices and fabrication plans for the grip-enhancing glove. Choosing a safe, comfortable, yet durable material to comprise the interior of the device will require further research and planning. Moreover, the budget will need to be defined by the client to ensure that the final cost of the device does not exceed the determined amount. Funding from an affiliated University of Wisconsin-Madison program will make ordering materials and paying for other expenses simple. As materials are ordered and fabrication begins in mid-October the device is expected to finish fabrication no later than the first week of November 2024. Afterward, the prototype will be tested in the aforementioned ways to ensure it meets the client's requirements. If necessary adjustments will be made to the prototype before it is ready for a final presentation in early December. In future semesters, biosensors and electronic components will be incorporated into the glove.

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# *Appendix*

## Appendix I: Product Design Specifications

### Function

The client, a hemiplegic stroke survivor, has requested the fabrication of a grip-strength mechanism that improves the grip function of their paralyzed hand. Grip strength is defined as the power generated by the hand and forearm muscles, impacting one’s ability to hold, pull, or lift objects [1]. The device will stimulate the hand to promote grip strength by forcing the hand into grip position and by providing real-time biofeedback of the measured grip strength. It must be adjustable allowing for gripping of various sized objects and must allow extension of the hand to release the object. The mechanism must be easily sanitized and should be used with minimal assistance. Following usage of the device, a hand dynamometer will measure the clients improved grip strength [2].

### Client requirements

- The device must be easily attached and detached on the user's hand without the need of additional support or involving lots of fastening procedures.

- The product must be applicable for both physical training sessions and common daily-life applications outside of sessions.
- The device must adequately stimulate initial support for the hand to open or close to desired angles for accomplishing specific tasks such as holding onto training instruments.
- Specific device intended for one client participating in the UW Adapted Fitness program, but later on could be applicable for usage to others with similar needs.
- Continuous in-person interactions with the specific client during their training session to further analyze and discuss the mechanism and development of the prototype.
- Must be easily sanitized for daily usage, even for domestic, personal purposes.

## Design requirements

1. **Physical and Operational Characteristics**
    a. **Performance requirements:**
        i. The main performance requirement of this device is to improve user's grip strength by providing assistance on physical movements of hand's flexion and extension. This device is meant to effectively recover the grip power of the patient after they have experienced a stroke.
        ii. The device should consist of elastic materials for easy self attachment capability along with consistent physical support and real-time biofeedback of measured grip strength that is easily transmittable for further analysis.
        iii. The target goal for improving user's grip strength is to reach above 26 kg which is the standard for weak grip strength [2]
    b. **Safety:**
        i. The smart grip mechanism must allow for rapid hand extension if the gripped object needs to be dropped in an emergency.
        ii. The device must be fabricated from a biomaterial that does not irritate the skin when exposed to sweat.
        iii. All electronic components of the device must be properly stored and labeled, following ISO Standard 10218 [3].
    c. **Accuracy and Reliability:**
        i. The device must allow the client to grip varying sized objects consistently. The grip strength of the device will be measured to ensure it is functioning properly.
        ii. All biosensors and electronic aspects of the device must report accurate biofeedback and provide guidance on next stages of training sequences.
    d. **Life in Service:**
        i. The device will be used weekly during the client's hour-long adapted fitness sessions. The device must withstand all workouts and must be easily cleaned. At a minimum, the device must last for an entire semester, spanning 5 months.
        ii. Ideally, the device will remain functional for several years. If parts of the device wear down over time, it should be easily replaced.
        iii. If biosensors or electronic components are used, the device will need to be charged from an external power source.
    e. **Shelf Life:**
        i. The device should be stored in a cool and dark place away from any UV light, ozone, moisture, or heat [3]. Competing medical gloves can be safely stored for 3-5 years [2].

ii. Any internal batteries should be stored separately and follow ISO Standard 10218 [4].

f. **Operating Environmen**t:
   i. The device will be mostly used in indoor environments under standard air conditioned room temperature (68-72 ℉) [5].
   ii. The device must be easily sanitized using medical-grade disinfectant in between usage and should be water and erosion-proof.
   iii. The device will be stored at the Adapted Fitness training facility and should be easily accessible for client's usage for weekly training sessions.

g. **Ergonomics:**
   i. The device should be conveniently and automatically equipped to the hand for grip improvement without much use of physical involvement directly related to hand and wrist. In general, the user must not apply more than 15-20% of their maximal strength to avoid excessive fatigue and injury risk. [6].
   ii. Turning and twisting motions such as opening a jar should also require minimal torque to prevent strain on the forearm, wrist, and hand muscles. A similar mechanism from mobile blood pressure cuff can be applied to achieve this objective with an instrumental application with direct command inputs for grasping and releasing actions on the hand.

h. **Size:**
   i. The device will be adjusted in size to fit the client's hand. It should cover the fingers and palm in which the gripping motions are involved.
   ii. The average glove size for adult males is 8.5 to 9.5 inches, measured around the palm of the dominant hand [7].
   iii. Competing devices range in size, with a large glove fitting wrists sizes of 7.1 in to 8.7 in and the distance from the wrist to the tip of the middle finger being 7.7 in to 11.0 in [8].

i. **Weight**
   i. The device will be made for a survivor of a stroke with limited mobility on the side of the body of which the device will be on so the device will need to be light enough as to not weigh down or affect the mobility of the client's arm. Further discussion with the client will be done in order to determine a specific weight that works best for the client's situation.

j. **Materials**
   i. The device will be made with a comfortable fabric which will go onto the client's hand. The fabric will need to be comfortable to wear for an extended period of time and will also need to have a strap made with velcro or something similar in order for the device to stay comfortably in place throughout the ranges of motion that the device will go through during use.
   ii. The device will also need important hardware on the top of the hand in order for the device to operate. Some of this hardware could include wires, motors, pressure sensors, batteries, or other needed components.

k. **Aesthetics, Appearance, and Finish**
   i. The device needs to be safe and comfortable to wear for extended periods of time. The hardware on top of the hand needs to be well organized and concealed so that the hardware stays protected, does not affect the use of the device, and looks organized and appealing to the eye. Since the device is initially intended for an individual client, further customizations on the appearance can be added at the request of the client.

2. **Production Characteristics**
   a. **Quantity:**

i. This particular device is being custom designed for the client, therefore one final device will be produced.
ii. In the future, the device should be mass-produced using parameters specific to each individual. Regardless of dimensions, the same principles will be assigned to each glove to allow users to open and close their hands, and grasp objects of varying sizes firmly.

b. **Target Product Cost:**
i. The budget for the design is currently unknown, therefore costs will be kept to a minimum until funding is received.
1. Similar devices range in price from $70-$300. The mechanism should be within this range to make the product competitive [8].
ii. The project will be funded through the College of Engineering, by virtue of Mike and Ginny Conwary, the namesakes of the Conway Adapted Fitness space at the Bakke Recreation & Wellbeing Center.

3. **Miscellaneous**

a. **Standards and Specifications**
i. The device must be fabricated with a biomaterial that is easily disinfected and sanitized, following ASTM Standard E1837-96 [9].
ii. All robotic elements of the smart grip enhancement device must adhere to ISO Standard 10218 [4].
iii. When quantifying the grip-strength of the glove-like mechanism, the measurements must comply with ASTM Standard F2961-24 [10].

b. **Customer**
i. The intended customer for the grip-strength mechanism is a hemiplegic stroke survivor. The customer desires a product that improves the extension and gripping capabilities of paralyzed hand muscles.
1. The device should be user friendly, as the customer requires assistance when exercising and gripping objects.
2. The mechanism must be lightweight to ensure the customer can lift the product.
ii. The smart grip enhancement device will be designed specifically for the customer, meaning it must be adjustable to their hand and forearm measurements.

c. **Patient-related concerns**
i. The customer's medical history will be shared with the product design team. Their medical history must remain confidential and all team members will undergo proper HIPAA training.
ii. The device must be easily sanitized using Lysol disinfectant spray when used in the Adapted Fitness facility.

d. **Competition**
i. Competing designs include the General Purpose Gripping Aid, manufactured by the company Active Hands. The glove-like design forces the hand into a fist shape, allowing for gripping of various sized items [8].
1. The gripping aid is fabricated from tough webbing and neoprene, making it machine washable.
2. The device has adjustable straps to accommodate the gripping diameter of the object. Since it fastens the user's palm to the gripped item, the object could not be easily released in an emergency situation.
3. The gripping aid costs between $70.00 and $100.00, depending on the size and color.

ii. The Exo Glove, developed by Kyujin Cho at Seoul National University, is a wearable robotic glove that allows paralyzed users to grasp and pinch objects. The device consists of a wearable three-finger glove and a tendon actuation system that is motor controlled.
    1. The robotic glove is fabricated from silicone, making it waterproof and easily sanitized.
    2. The electronic components of the device measure the wrist's angle during motion, including finger movement.
    3. The device has a pinch force of 20N and a grasp force of 40N [11].

iii. The Gripping System, Apparatus, and Methods Patent, US8192296B2, describes a two-member mechanism that provides users with weakened hand strength a tighter grip around everyday objects. The mechanism consists of a mating glove that fastens to compatible material on the object to be gripped [12].
    1. The device is fabricated from hook-and-loop fastener material that mates with retrofit tape wrapped around the graspable surface.The device must be fastened to both the user's hand and the gripped object, which might require assistance to use.

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## Appendix II: Expense Table

| Item | Description | Manufacturer | Mft Pt# | Vendor | Date | QTY | Cost Each | Total |
|---|---|---|---|---|---|---|---|---|
| **Skeleton Glove** | | | | | | | | |
| N/A | | | | | | | | |