

Project Documentation 2

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1 Design for Manufacture and Assembly

2 Ethics Statement

We reference the Code of Ethics for the Physical Therapist. With our physical therapy hand device we aim to address treatment for those who would benefit from remote commitment to treatment[2][3], adapting to modern trends to benefit therapists[6] and clients[7] and serving those without consistent access to therapy[8].

- Principle 2: Physical therapists shall be trustworthy and compassionate in addressing the rights and needs of patients and clients.
- Principle 3: Physical therapists shall be accountable for making sound professional judgments.
- Principle 6: Physical therapists shall enhance their expertise through the lifelong acquisition and refinement of knowledge, skills, abilities, and professional behaviors.
- Principle 7: Physical therapists shall promote organizational behaviors and business practices that benefit patients and clients and society.
- Principle 8: Physical therapists shall participate in efforts to meet the health needs of people locally, nationally, or globally.

Code of Ethics for the Physical Therapist

3 Budget for Prototype

Item	Quantity	Vendor	Price per Unit (\$)	Total Cost (\$)
Flex Sensors	5	[Spectra Symbol]	10.85	54.25
Microcontroller (ESP32)	1	[AITRIP]	15.99	15.99
Glove	1	[LYDTICK]	16.99	16.99
Wiring & Connectors	1 (pack)	[Spark Fun]	5.97	5.97
Battery Pack	1	[Raion Group]	29.95	29.95
3D Print Filament	1	[AMOLEN]	29.99	29.99
Actuator (Micro-Servos)	1 (10 pack)	[Smraza]	18.99	18.99
Server Cost (Monthly)	N/A	[AWS]	Free Tier	Free
Velcro	1	[ULINE]	20.00	20.00
TOTAL				192.13

4 Life Cycle Assessment

4.1 Goal and Scope Definition

4.1.1 Objective

The LCA aims to assess the environmental footprint of the Thera-Hand rehabilitation device, considering its:

- Energy consumption (power supply, servos, ESP32).
- Material usage (PLA, rubber, fishing line, sensors).
- Manufacturing and transportation impact.
- End-of-life disposal/recycling feasibility.

4.1.2 Functional Unit

A single Thera-Hand device is assumed to be used for 2 years before replacement.

4.1.3 System Boundaries

This LCA includes:

- Raw Material Extraction – Plastics, rubber, and electronics production.
- Manufacturing and Assembly – 3D printing, PCB production, servo motor production.
- Transportation – From manufacturing to users.
- Use Phase – Power consumption during operation.
- End of Life – Disposal, recycling, or potential reuse.

4.2 Inventory Analysis

4.2.1 Material Composition and Impact

Component	Material	Environmental Impact
Frame & Housing	PLA (3D printed)	Low-carbon footprint, biodegradable under specific conditions
Sensors	Flexible PCB, resistive materials	Electronic waste, difficult to recycle
Actuators (Servos)	Plastic, copper wiring	High-energy manufacturing, limited recyclability
Power Supply	Electronic components, metal	Requires responsible e-waste disposal
Wiring & Fishing Line	Copper wiring, nylon	Small footprint, but non-biodegradable

4.2.2 Energy Consumption(Use Phase)

Based on prior power consumption estimates:

Component	Power Consumption (W)	Usage per day (hours)	Annual Energy (kWh)
ESP32	1.25W	2	0.91 kWh
5 SG90 Servos	6.25W (idle) / 16.25W (peak)	1	5.93 kWh
Sensors & LED	0.15W	2	0.11 kWh
Total Estimate	7.65W - 17.65W	-	6-7 kWh/year

Table 1: Comparison: This is equivalent to a low-power LED bulb running for 3 months.

4.3 Impact Assessment (Environmental)

4.3.1 Manufacturing:

- Electronics production (ESP32, sensors, servos) has the highest carbon footprint.
- 3D printing (PLA) requires energy but has a relatively low impact compared to metals.

4.3.2 Use Phase:

- Low electricity consumption (6-7 kWh/year) makes it energy-efficient.

4.3.3 End-of-Life Considerations:

- PLA parts are biodegradable in industrial composting but not in landfills.
- Servos, wiring, and PCBs require responsible e-waste recycling.

4.4 Interpretation and Recommendations

4.4.1 Key Findings

- Low Energy Consumption: Thera-Hand is energy-efficient in use.
- Minimal Carbon Footprint for PLA: The frame is eco-friendly, but plastics must be disposed of properly.
- E-Waste Challenge: Sensors, servos, and the ESP32 must be recycled properly.
- Transportation Impact: If shipped globally, the CO₂ footprint increases.

4.4.2 Recommendations

- Optimize 3D Printing Material: Use recycled PLA or biodegradable TPU to reduce waste.
- E-Waste Collection Plan: Offer a recycling take-back program for electronics.

- Reduce Servo Impact: Use low-power or energy-efficient servos if possible.
- Sustainable Packaging: Use biodegradable or recycled materials for packaging.

4.5 Conclusion

- Thera-Hand is a low-energy, partially sustainable device.
- The biggest environmental concern is e-waste disposal of sensors and servos.
- Efforts to recycle electronic components and use sustainable materials can improve its eco-friendliness.

5 Test Plan

5.1 Ability to be turned on/off

The device should have the ability to be turned off separately from being unplugged.

5.1.1 Goal

The Device should be able to be turned on and off while still connected to a direct power source.

5.1.2 External Factors

Make sure the power connection is stable and not underloaded.

5.1.3 Equipment

Hand device with external bank, Power Source.

5.1.4 Steps

1. The device should not be connected to any person.
2. The device should be plugged into an AC stable power supply of at least 120V. A common wall socket is preferred.
3. Load any basic exercise and wait longer than 10 seconds.
4. Turn off the device by pressing the power button on the box connected to the wall. Make sure to press the power button before the exercise has finished.
5. Observe and measure the time it takes for the device to stop movement.
6. Repeat steps 3-5 multiple times with differing exercises.

5.2 Ability to download/save metrics

Data should be stored and sent remotely after each exercise is completed.

5.2.1 Goal

The Device should be able to remotely send data to an external device that can store data.

5.2.2 External Factors

Unstable power supply, unstable internet connection, and connectivity issues.

5.2.3 Equipment

Hand device with external bank, Power Source, Separate device connected to internet and connected to device.

5.2.4 Steps

1. Plug the device into a stable 120V AC power supply, preferably a wall outlet.
2. Load the exercise onto the device and begin the workout. Preferably a short workout routine.
3. Connect the therapist's device to a stable internet connection.
4. Pair the device to a therapist's computer, allowing it to download and store the device's workout data.
5. Start the workout and wait for it to finish.
6. Observe the download of the device

5.3 Weight

Determine the weight of the device that is worn on the hand. Under two pounds.

5.3.1 Goal

The device should weigh under 2 lbs or 1kg.

5.3.2 External Factors

The scale should be accurate enough to detect under five pounds and should be zeroed before use.

5.3.3 Equipment

Hand device without external bank, small scale.

5.3.4 Steps

1. Unplug the device from the power bank and computer.
2. Place the device on the scale. The glove should be dry and empty. Strings should be attached from servos to fingers.

5.4 Accuracy of repetition counting

The device should be tested to report as many repetitions as are being performed. We need to know the degree of error of our data.

5.4.1 Goal

The device should count the repetitions performed ideally with perfect accuracy.

5.4.2 External factors

The device should be properly calibrated to recognize when a full range of motion repetition has occurred.

5.4.3 Equipment

Hand device with external bank, Power Source, Separate device connected to the internet and connected to the device.

5.4.4 Steps

1. Plug the device into a 120V AC outlet.
2. Turn the device on and begin basic squeeze exercises, where fingertips must touch, for 10 seconds.
3. While the device records repetitions, manually count how many repetitions occur until the time is over.
4. Compare the number of repetitions the device reports to the number of repetitions observed.

5.5 Individual controllability

Each finger should be able to operate independently of any other finger.

5.5.1 Goal

Verify that each finger is independently programmable and movable.

5.5.2 External factors

Individual anatomy and flexibility of those being tested.

5.5.3 Equipment

Hand device with external bank, Power Source, Separate device connected to the internet and connected to the device.

5.5.4 Steps

1. Plug the device into a 120V AC outlet.
2. Turn the device on and verify each finger individually can be pulled in individually.
3. Verify each finger individually can be extended back out.

5.6 Resting state

The device should return to a resting state after the completion of each exercise.

5.6.1 Goal

The device should be verified to return to a neutral state after each exercise is completed.

5.6.2 External factors

Someone's anatomy or flexibility may prevent a typical "neutral" resting state.

5.6.3 Equipment

Hand device with external bank, Power Source, Separate device connected to the internet and connected to the device.

5.6.4 Steps

1. Plug the device into a 120V AC outlet.
2. Turn the device on and begin an exercise.
3. After completion of the exercise, verify that the device has returned to its neutral resting state.

Name(s)	Date and Location
Test 1: Did the power turn off? (Yes/No)	
Test 2: Was data remotely sent? (Yes/No)	
Test 3: Weight: (kg/lbs)	
Test 4: What accuracy were the repetitions counted to? (%)	
Test 5: How many fingers were individually controllable? (0-5)	
Test 6: Did the device return to a resting state? (Yes/No)	

Table 2: Test Log

6 Updates