Assistive Garment For Disabled People

Sponsor: Dr. Peter Popper

MEEG304: Machine Design - Elements
TEAM G6

Group Members:

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Project Summary

The goal of this project was to design and build a prototype for a garment that assists disabled people in moving their arms up and down. While there was a struggle to meet in person because of COVID and group members not being able to be in the same location, we planned and tested this prototype in person to the best of our abilities. All design information, testing details, and drawing packet are included in this report, and will be passed onto Dr. Popper.

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Introduction

Soft robotics is a growing field in which engineers design and build mechanisms from pliable materials such as fabric, rubber, fluids and gases. The main purpose of this project is to help anyone who does not have the ability to raise and lower their arms under their own power. Our sponsor asked us to use a combination of a tube and air pressure to create a mechanism that helps disabled people lift their arm to gain maneuverability in everyday life.

Project Scope

The goal of this project is to design and build a prototype for a garment that helps disabled people move. More specifically we are attempting to use soft robotics to help a disabled user gain the ability to raise their arm.

Performance Requirements

Table 1: Design requirements for the project are listed in the table below.

Priority	Need/Want	Description	Target Value/Metric	Reference
1	The user must be able to raise and lower their arm	Must work on command	-The arm must reach 45° in a minute -Must lift at least 12.65 lbs	[1] Average weight of an arm
2	Acceptable sizing	Should fit under clothing on any average size adult	Tube: No longer than 2 feet Compressor: No bigger than a 6 inch by 6 inch space	[2] Average length of an arm
3	Comfortable	Must be comfortable to be worn for long periods of time	-Wrap the tube in a soft fabric -Make sure everything stays in place for at least 5 hours	
4	Safe for all ages	No sharp components	Must pass safety test	

Concept Development and Selection

Although each of our design concepts [Appendix B] are very similar, we made sure to develop ideas that honored not only our sponsor's metrics, but also our target values. If you look at our design matrix [Appendix C] you can see that it was a tie between concept 2 and concept 3, therefore we decided to combine the two ideas into one. We used the inflatable tube design from concept 3 and applied it to the method in concept 2.

Final Design Concept

For our final design concept, we decided to go with a combination of our previous concepts [Appendix B]. Using components of all other designs, we incorporated the jacket of concept 1, the angled design of concept 2, and finally the multiple tubing of concept 3. The final design consists of a jacket that the user would put on first, followed by a harness system (multiple straps secured with rivets) that wraps around the right shoulder and torso, and finally the tubing itself is routed through the harness and back onto the jacket, connected on the arm via the harness and wrapped with a garment. The pressurization control is also located at the user's other hand.

Figure 1: Above image shows the assistive garment. Left is the front view. Right is the rear view.

The final design could be improved upon in terms of ease of putting on, as there are essentially three separate components of this prototype (jacket, harness, tubing). This design also makes use of a bungee strap to hold the tube at the desired angled position, so that it can still stretch and extend when pressurized. Final Design drawings can be seen in Appendix D

Prototype Design and Development

Because of the large majority of our classes being online and all group members not being in one location, it was difficult to arrange proper in person meetings for our prototype development. As a result, most prototyping/testing happened near the end of the semester, and only two group members were able to participate in doing so. We began by looking into and deciding which materials we would be using. As seen in the bill of materials [Appendix A], we decided on working mainly with pneumatic air tubing, water-repellent cotton fabric sheets, and a nylon sleeve. The bill of materials also mentions a rubber bladder, however we did not pursue this and instead utilized pressurized air supplied from the machine shop. In a future design, an air bladder would likely be used to keep the air centralized within the design itself.

<u>Note: The images that will be described for prototyping can be found in Appendix E</u>

To start off our prototyping, we began by taking the long pneumatic air tube and folding it back over on itself multiple times (Figure 1). We did this so that the tubing would only have to be pressurized at a single tube entrance, and closed off at one exit. This was then secured with zip ties, and this would create our base tubing for our final design, which can be seen in Figure 2. In order to do some more testing on this tubing, we tested pressurization with one tube (Figure 3). In order to secure the air within it, we used a screw and a hose clamp at the end of the tube. We did not have proper fittings, however, and as a result air still managed to escape, and the tube did not fully extend. Because of this issue, we wanted to try pressurization with a bicycle tube as well, since we already had access to the proper fittings. To do this, the bicycle tube was secured within the nylon sleeve, and then fed compressed air. Upon doing so, we noticed that the tube was escaping the ends of the nylon sleeve. We tried again with a longer cut of nylon to cover the whole bike tube. The problem here, however, was that the ends of the nylon sleeve were not closed off. As a result, when pressurized, all the air went to one end of the sleeve, and caused the bike tube to explode (Figure 4). Moving forward from this, we pursued our original design of the folded over pneumatic air tubing. Using this tube, we created a system to hold and secure it onto a user. As previously stated in the final design concept, this consisted of a jacket, custom made harness, and the tubing itself (Figure 5 and 6). Finally, the pressure control was located at the user's opposite hand (Figure 7).

<u>Note: Final Prototype is a **MOCK UP**, and images do not actually show pressurized tubes, rather the user's arm in a raised position.</u>

Performance Validation (Testing and Results)

To test our ideas we tried pressurizing pneumatic tubing and a bicycle tube in a prototype of our design. When we tried the pneumatic tubing we found that the air was escaping, not allowing the tubing to become rigid. We then tried using the bicycle tube and had trouble keeping it contained in the nylon, once we did get it contained the result was the bicycle tube popped at an unknown pressure value. Although we acquired the proper fitting for the pneumatic tubing we were not able to schedule time in the design studio to run more tests.

Based on our limited resources and time available in the lab we found it difficult to come up with a direct relationship between the initial angle of the tube with the horizontal and the resulting angle the arm could be lifted, or the effects of using multiple smaller tubes as opposed to one big tube. However, based on our preliminary testing we believe that with proper resources experiments can be developed to find these relationships, and that they may show promising results. Examples of these possible test setups are shown in Appendix F. Based on our preliminary tests to determine our design concepts we expect to see these tests yield a correlation where increasing the initial angle will increase the resulting arm lifted angle, as well as an increase in the weight lifted divided by the cross sectional area of the tube, as the diameter of the tube decreases. While these correlations were seen from basic less precise tests during our concept development, we believe that the suggested tests will give the required data to determine the most efficient design based on these concepts.

Conclusions

Our team's assistive garment is a very unique design, mainly being in the multiple tube system, as well as the angled tube system. We do believe that it could be a possible solution for the problem presented to us, however further testing would be required to come to a full conclusion. The thought process behind these designs is relatively straightforward, and all construction of the design consists of cheap and easy to use materials. While there are inconsistencies of testing within this design, we believe that it would be worth pursuing for its unique properties.

Recommended Next Steps

Our recommended next steps would be focused around seeking improvements for areas where we struggled. To start, we would likely try the use of a different type of tubing that would allow for more freedom of movement. The pneumatic tubing that we used felt somewhat stiff, and was hard to shape nicely onto our designed garment. A type of tubing that is a good balance between that and the bicycle tube would likely be something that we'd try out next. We would also make the designed garment into one piece to allow for ease in putting it on. Our current prototype uses an overhead jacket, which someone who needs this product would obviously struggle with putting on. A future design would use some sort of button up or zip up garment for most ease of use. Our final suggestion would be that of Dr. Popper's, which is the use of a suspension system to help lift the arm. While we do not have a set plan on how we would incorporate this, it is definitely something that would be considered in a future design.

Final Project Plan
See Appendix G for final Gantt Chart

Appendices

Appendix A: Bill of Materials

Table 1: A bill of materials used in the construction of the assistive garment.

Material	Size	Cost	Quantity	Total
Rubber bladder to contain air	8mm 5/16	$25	1	$25
Soft plastic tubing for air	ID: 3/16” OD: ⅜” Length: 10ft	$0.40/ft	5	$20
Water-repellent cotton fabric sheets	10ft	$1.15/ft	1	$11.50
Nylon Sleeve	ID: ¾” Expanded Diameter: 1” Length: 10ft	$14.96	1	$14.96
			Total	**$71.46**

Rubber Bladder to contain Air: ex: Rubber Bladder
Soft Plastic Tubing for Air ex: Air Tubing
Water-Repellent Cotton Fabric Sheets ex: Fabric
Nylon Sleeve ex: Nylon Sleeve

Appendix B: Preliminary Concepts

Although the first concept seems efficient, we decided to go with a combination of concept 2 and 3. This is because concepts 2 and 3 are more cost efficient, and they are also more unique.

Design Concept 1: In this concept, an inflatable tube goes over the shoulder to hold the arm up in place using the user's shirt. The tube would inflate and deflate on the user's command via a small portable air compressor.

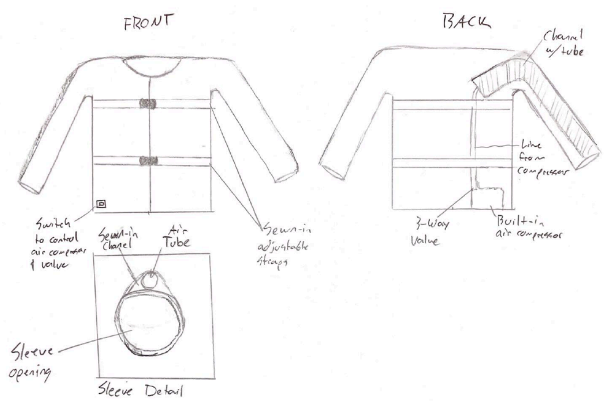

Figure 1: Design concept incorporating straps for security, with air compressor and inflatable tube for lift.

Design Concept 2: In this concept, an inflatable tube goes under the arm to hold the arm up in place connected to the user by a vest of straps. In this design there would also be a portion of the tube angled down the back at an angle slightly greater than 45 degrees to the horizontal. This portion would be inside a rigid tube. The other end of the tube would be inside a rigid tube fastened to the arm between the elbow and wrist. Also we might find the need to add some form of rigid rod to keep the arm straight. The tube would inflate and deflate on the user's command via a small hand/foot pump or an air compressor.

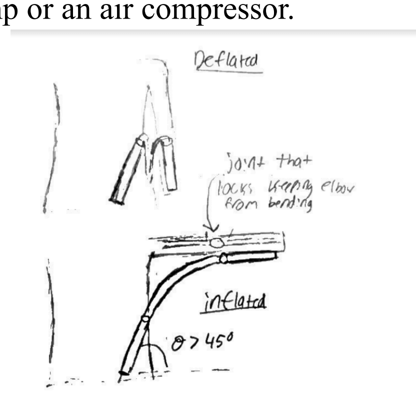

Figure 2: Design concept incorporating an air tube positioned under the arm to create lift.

Design Concept 3: Here, an inflatable tube goes over the user's shoulders and down one arm. The tube would have smaller tubes inside of the larger one and each inflate one at a time to provide the user with the option to raise the arm to any degree needed. To inflate and deflate the tubes, the user would use a hand/foot pump.

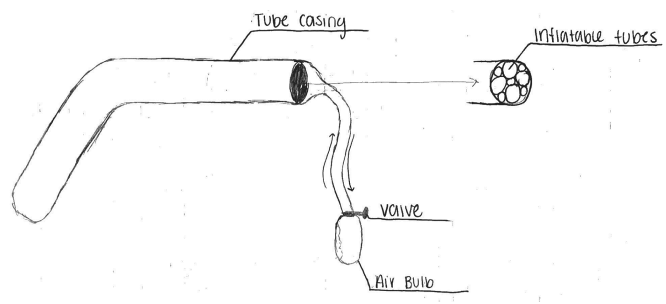

Figure 3: Design concept using multiple small high pressure tubes to create lift.

Appendix C: Decision Matrix

Table 1: Table showing what design criteria each concept possesses.

	Able to lift arm	**Acceptable Size**	**Comfortable**	**Safe for all ages**	**Cost**	**Total**
Concept 1	1	0	1	1	0	3
Concept 2	1	1	0	1	1	4
Concept 3	1	1	1	1	0	4

Appendix D: Final Design Drawings

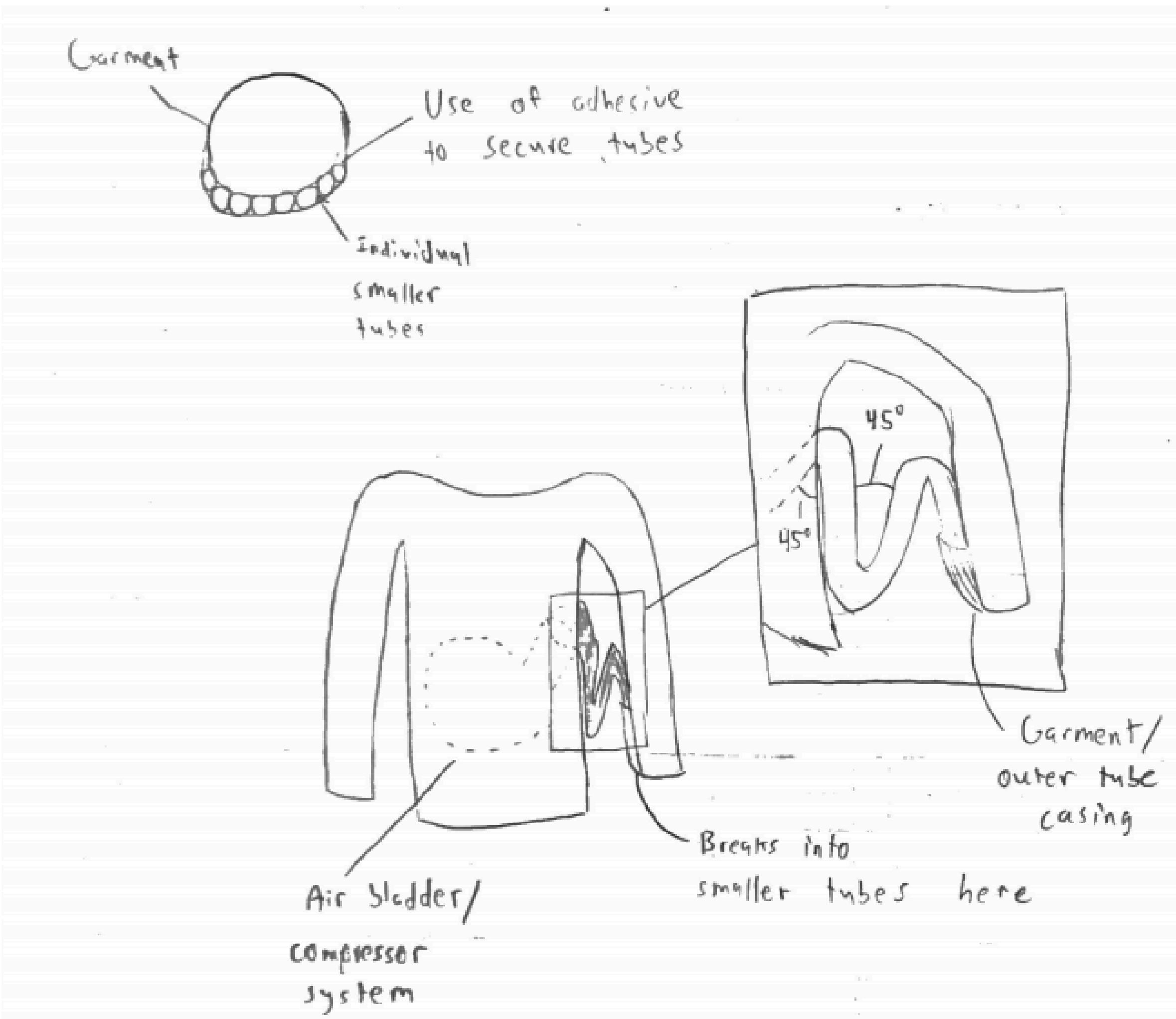

Figure 1: Final drawing of proposed prototype.

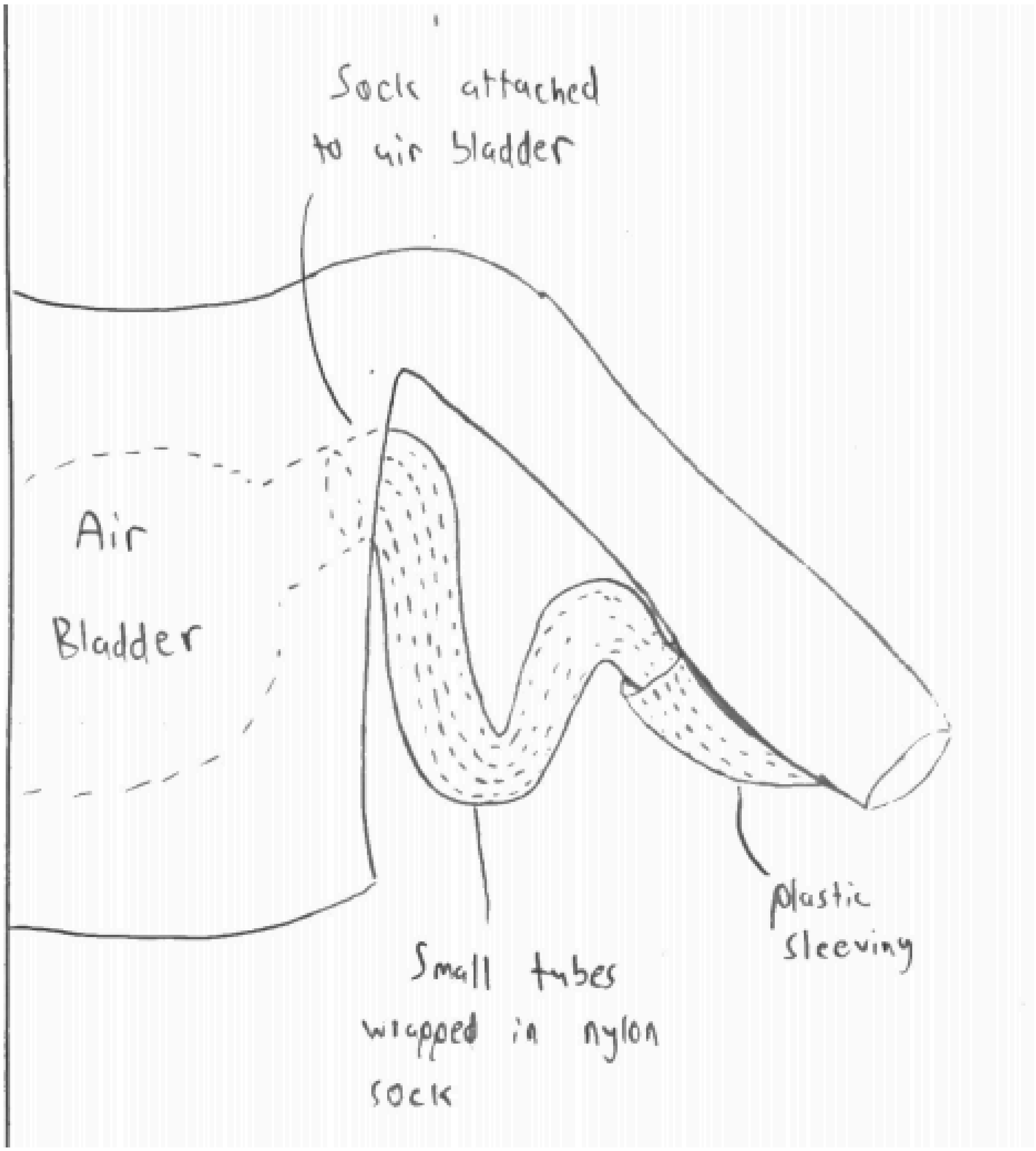

Figure 2: Drawing showing detail of air tube routing.

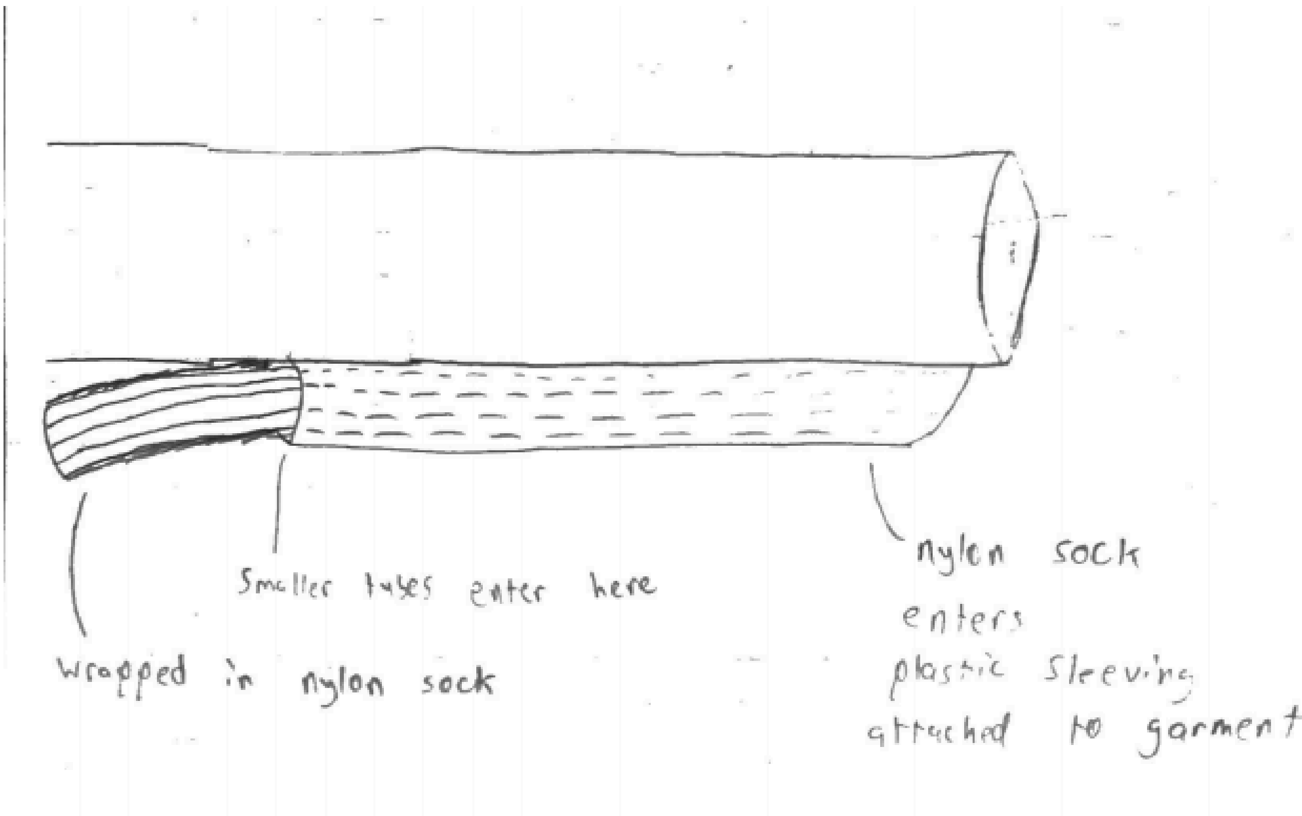

Figure 3: Drawing showing detail of multiple air tubes inserted in the channel.

Appendix E: Final Prototyping

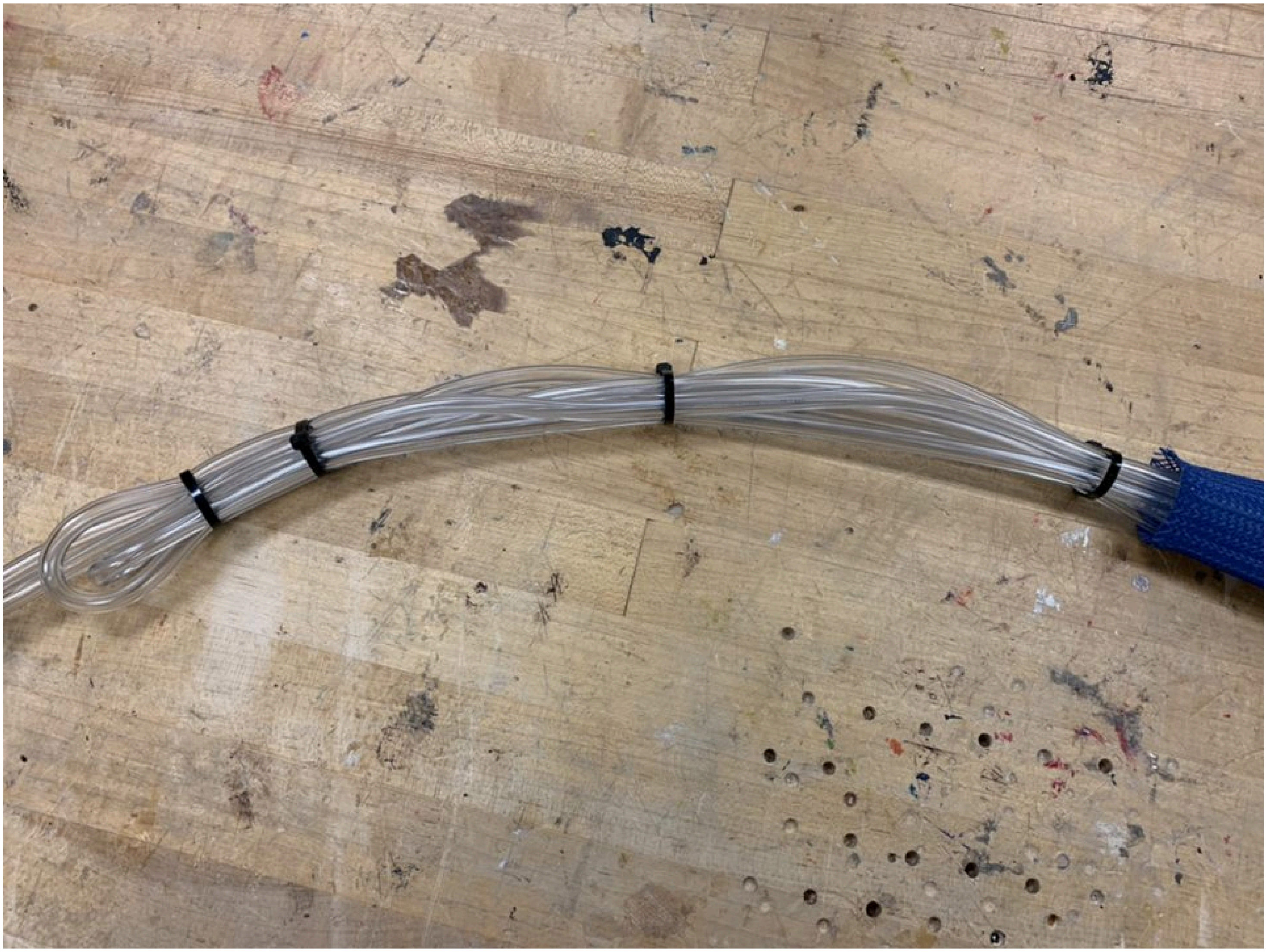

Figure 1: Single pneumatic tube folded over and secured with zip ties to make lifting tube

Figure 2: Air tube assembly inserted into nylon sleeve.

Figure 3: Single piece of tubing that was used to test effectiveness of material for garment.

Figure 4: The bicycle inner tube that was used inside the nylon sleeve. The red circled area indicates where the tube failed under pressure.

Figure 5: Front view of completed **Mock Up**

Figure 6: Back view of completed **Mock Up**

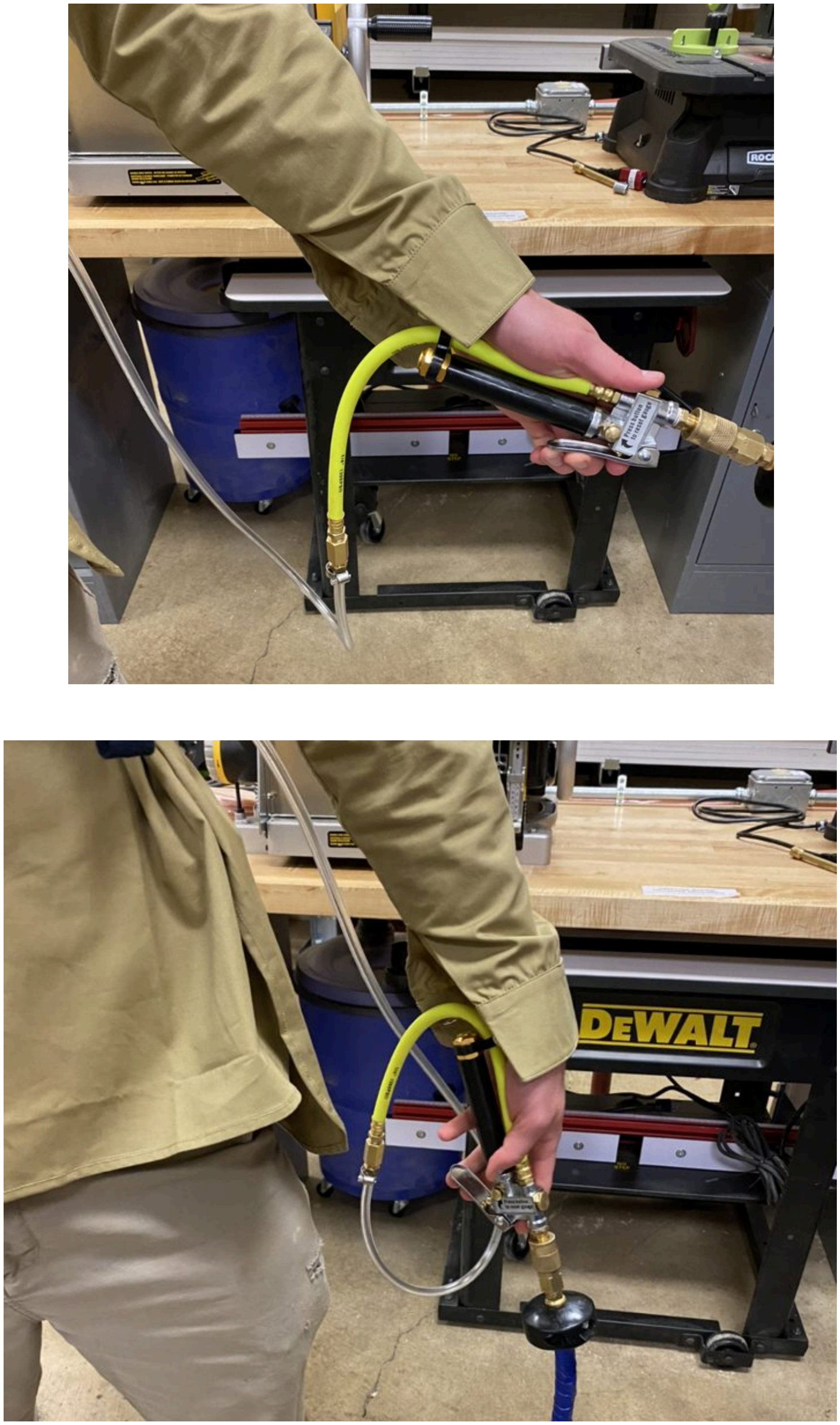

Figure 7: Air pressurizer located at user's opposite hand

Appendix F: Test Plans

Test 1: Starting tube angle

For this test we will begin by fixing a tube at multiple different starting angles (θ_s)and inflating it to a known pressure constant for each angle. We will have the tube fastened to a rigid beam of known weight, and measure the angle (θ_r) that the beam makes with the vertical axis for each starting angle. This test is designed to find a relationship between the starting angle and the angle the beam makes with the vertical to find the optimal value for θ_s. It is also likely that we will have to adjust the position of the grounded end of the tube in the vertical direction to measure the maximum resulting angle for each starting angle.

Test 2: Tube radius

The purpose of this test is to determine the optimal radius for each tube. The independent variable for this experiment will be the radius of the tube. The set up will be similar to test 1 at the optimal starting angle determined in test 1, however instead of measuring the resulting angle at a fixed weight we will measure the maximum weight to achieve a certain predetermined angle. The objective of this test is to determine the radius that results in the maximum weight vs cross sectional area of the tube to give us the most efficient option.

Test 1 Metric: Initial angle

1. Purpose and performance goal:

This test is meant to determine the optimal path for our tubes to achieve our goal for the angle of the arm. The results of this test should give us a relationship between the starting angle of the tube path (θ_s) and the resulting angle of the arm with the vertical axis (θ_r).

2. Test parameters:

Dependant variable: (θ_r)- angle between 'arm' and vertical axis

Independent variable: (θ_s)- starting angle of the tube path from horizontal axis and vertical position of fixed point adjusted by hand to yield the greatest possible resulting angle

Constants: W- weight of 'arm', pressure of tube, all geometric properties of arm, horizontal position of the tube starting point, and how the tube is connected to the arm.

3. Equipment and personnel:

- Rigid beam connected to tall structure by a hinge used to represent the arm

- 1 inflated tube
- Block used to adjust vertical starting position
- 3 Clamps to hold tube at a fixed starting angle on block and to hold block to tall structure
- String or zip ties to fasten tube to rigid beam

4. Procedure:

1. Secure tube to Rigid beam using string or zip ties
2. Clamp tube to Block at test angle
3. Adjust vertical position of block to approximate height with greatest resulting angle
4. Measure resulting angle
5. Repeat steps 2, 3, and 4 for various test angles

5. Data analysis:

Plot data and determine (θ_s) value with greatest (θ_r) value

6. Data collection:

Trial #	(θ_s)	Vertical position	(θ_r)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Test 2 Metric: Weight capacity based on tube radius

1. Purpose and performance goal:

This test is meant to determine the optimal tube radius for the most spatially efficient design to achieve our Weight goal. The result of this test should give us a relationship between a tube's radius and the weight it can hold divided by its cross sectional area.

2. Test parameters:

Dependent variable: W- measured weight of arm to achieve certain θ_r

Independent variable: r- tube radius

Constants: angle between 'arm' and vertical axis, starting angle relative to horizontal, pressure in tube

3. Equipment and personnel:

- Light Rigid beam connected to tall structure by a hinge used to represent the arm
- multiple inflated tubes all at same pressure
- Block used to adjust vertical starting position
- 3 Clamps to hold tube at a fixed starting angle on block and to hold block to tall structure
- String or zip ties to fasten tube to rigid beam
- Set of weights to apply to light rigid beam

4. Procedure:

1. Assemble the mechanism to the maximum θ_s determined in experiment 1
2. Fasten Trial 1 tube
3. Add weight to Light Rigid beam until θ_r is a certain value say 45 degrees
4. Record weight
5. Repeat for each radius

5. Data analysis:

Plot r vs $\frac{W}{\pi r^2}$ determine r value with greatest $\frac{W}{\pi r^2}$

6. Data collection:

Trial #	**r**	**w**	$\frac{W}{\pi r^2}$
1			
2			
3			

4			
5			

Appendix G: Final Gantt Chart

Table 1: Gantt chart showing project schedule.