

Testing Report – Muscle Optimization Stage III

Team: P15001: Active Ankle Foot Orthotic

Engineer: Noah Schadt – Mechanical Engineer

Engineer: Tyler Leichtenberger – Mechanical Engineer

Test Date: 11/29/2014

Related System: Actuate Muscle (ABBBBA)

The purpose of this test is to design and construct an optimized muscle for the integrated system. This test will decide our final muscle selection for our design and help drive our integrated testing going forward.

Testing Procedure

Supplies

1. Orange wire Sleeving (M10)
 - a. Muscle sleeving of various lengths and diameters
 - b. Latex surgical tubing A/R
 - c. Silicon surgical tubing A/R
 - d. Plastic end cap plug
 - e. Plastic inlet fitting
 - f. Adapters A/R
 - g. (2x) Worm clamps
 - h. 3/4in latex tubing (for protection)
2. Pressure regulator
3. Transparent air line tubing (A/R)
4. 1/4in quick connect to shop tank quick connect (2 pieces screwed together)
5. Shop air tank
6. Packing tape/wire ties
7. Ruler/Calipers
8. Weights (see Table 1: Individual Weights)

Setup

The weights used in the tests consisted of the following individual weights:

Weights	lbs
Weight (1)	4.59
Weight (2)	4.63
Hangar (3)	0.93
Dumbbells (4)	2.00

Table 1: Individual Weights *average of (1)&(2)

The weights were configured in one of the following arrangements as shown in Table 2:

Weight Configuration	lbs	Config. #
One main and dumbbells (1)(3)(4)	7.51	W1
Two main weights (1)(2)(3)	10.1	W2

Table 2: Weight Configurations

Two unique muscles were tested in this stage. Continuing with terminology from stage I, the muscles are titled using M# notation starting with M10 since there were nine muscles tested previously. The orange sleeving is the sleeving used previously, with 3 strands per weave, while the pink sleeving is the smaller, single weave sleeving.

Muscles	Muscle #	L ₀ (in)
<i>Silicon with orange sleeving</i>	M10	6.5
<i>Silicon with pink sleeving</i>	M11	6.5

Table 3: Stage III Muscles

A total of 4 test configurations were arranged from these muscles and weights. Each test was completed **3 times**.

Total Configuration	Test #	lbs	Test Name
M10 & W1	Tests 16,17,18	7.51	M10) 7.51lb
M10 & W2	Tests 19,20,21	10.1	M10) 10.1lb
M11 & W1	Tests 22,23,24	7.51	M11) 7.51lb
M11 & W2	Tests 25,26,27	10.1	M10.1) 10.1lb

Table 4: Test Configurations

The test rig measurement was similar to that shown in Figure 1, from stage II of testing, measuring the displacements of the weights. However, the test rig was set up as shown in Figure 2. For this stage III set up testing, placement and measurement methods did not vary from muscle to muscle, as the tests were performed on the same day with the same setup. Also, for the first time, no hands were needed to hold the ruler or the muscle, as everything was attached directly to the table for ease of use, repeatability, and timeliness. A twist tie was attached to the weights that moved with the deflection of the muscle, providing an easy datum to read deflection measurements.

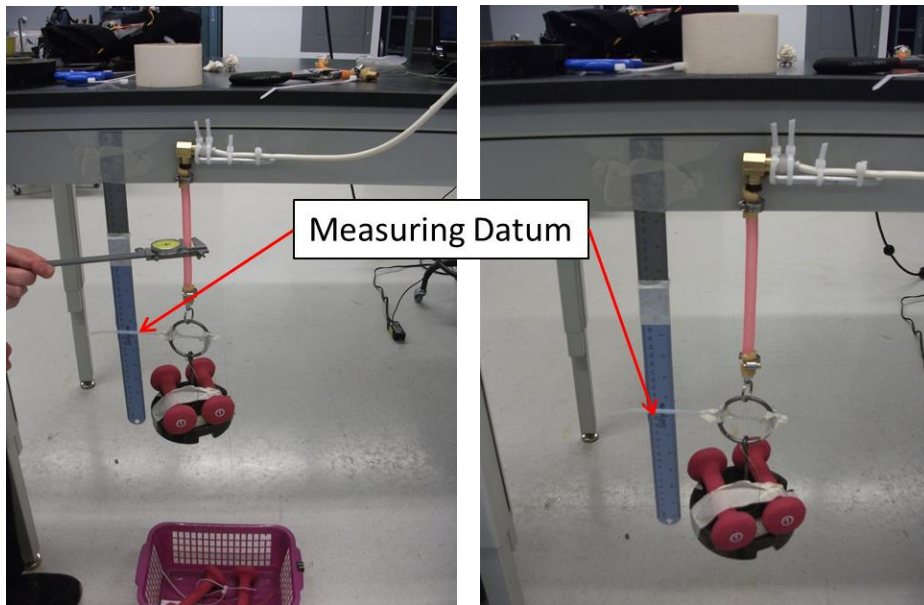
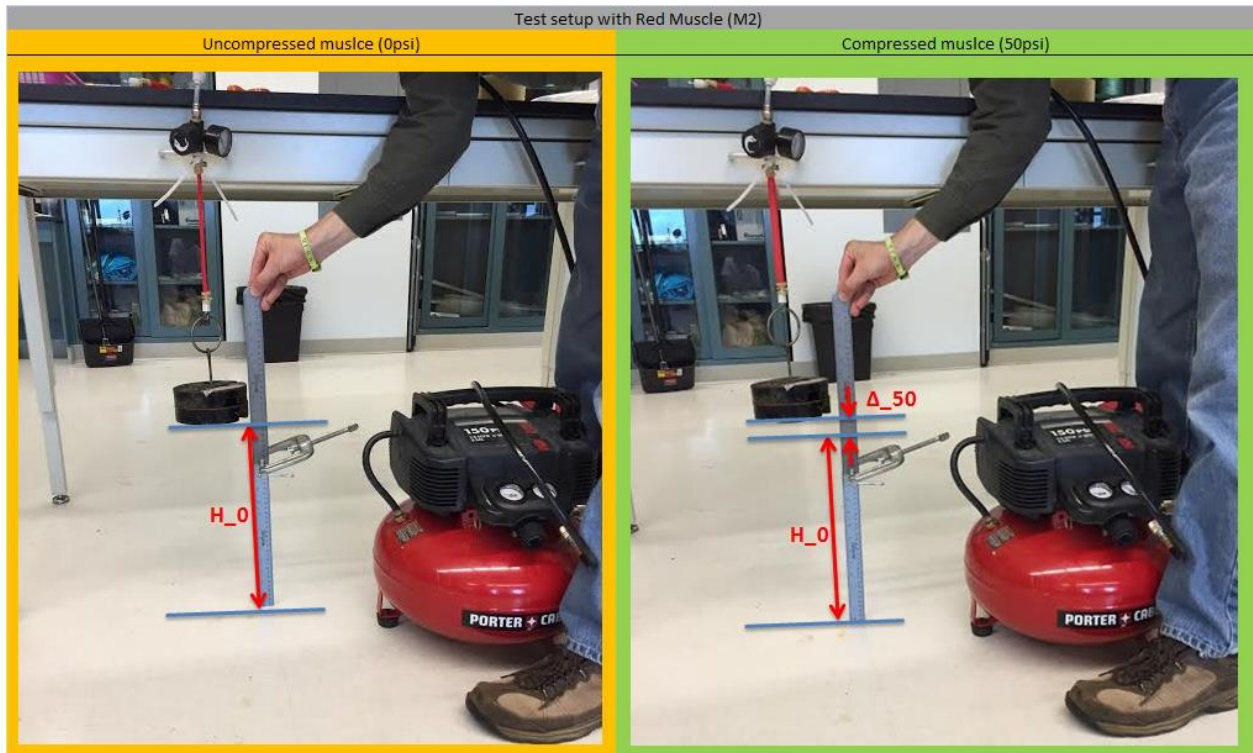


Figure 1: Test Rig

Procedure

The tests were performed by varying the pressure and measuring the height and outer diameter. There is little deflection from 0-20psig so measurements typically began at 20psi and increased by 10psi with 55psi often shown for clarity. The grey boxes represent linearly averaged values for line continuity since not all 55psi measurements were taken. The muscle diameter at 60psi is shown on the right for most muscles.

Pressure (psig)	0	20	30	40	50	55	60	65	70	Dia @ 60	L _e	Est. Steps @60psi	Uncorrected	
													V @ 60psi	step prediction
M10) 7.51lb	0.00	0.19	0.44	0.81	1.06	1.13	1.25	1.31	1.38	0.62	6.50	1054	1.12	6025
M10) 7.51lb	0.00	0.13	0.31	0.69	0.94	1.06	1.13	1.19	1.25	0.62	6.50	1010	1.17	5774
M10) 7.51lb	0.00	0.19	0.38	0.75	1.00	1.13	1.19	1.25	1.19	0.63	6.50	970	1.22	5543
M10) 10.1lb	0.00	0.13	0.25	0.50	0.81	0.94	1.06	1.13	1.19	0.60	6.50	1079	1.09	6167
M10) 10.1lb	0.00	0.13	0.25	0.50	0.81	0.94	1.06	1.19	1.19	0.59	6.50	1105	1.07	6316
M10) 10.1lb	0.00	0.13	0.25	0.50	0.81	0.94	1.06	1.13	1.19	0.60	6.50	1097	1.08	6266
M11) 7.51lb	0.00	0.13	0.31	0.50	0.81	0.94	1.00	1.06	1.19	0.53	6.50	1430	0.83	8173
M11) 7.51lb	0.00	0.13	0.31	0.56	0.81	0.94	1.00	1.13	1.19	0.53	6.50	1443	0.82	8248
M11) 7.51lb	0.00	0.13	0.31	0.56	0.81	0.94	1.00	1.13	1.19	0.52	6.50	1484	0.80	8481
M11) 10.1lb	0.00	0.13	0.25	0.44	0.63	0.75	0.88	1.00	1.06	0.51	6.50	1558	0.76	8904
M11) 10.1lb	0.00	0.13	0.25	0.38	0.63	0.75	0.88	0.94	1.06	0.52	6.50	1479	0.80	8449
M11) 10.1lb	0.00	0.13	0.25	0.38	0.63	0.75	0.88	0.94	1.06	0.51	6.50	1566	0.75	8947

Steps estimated based on a 4500psi 90cu-in tank

Linear avg Aprx. Dia.

Table 5: Stage III Corrected Deflection Results

All unspecified units in the test matrix are expressed in inches.

Results

The results of Table 5 were plotted directly into Figure 2 for deflection, and Figure 3 for estimated steps, and color coded for identification.



Figure 2: All: Color by Weight- Deflection



Figure 33: All: Color by Weight- Steps

Conclusions

From this test we have concluded that the optimal muscle should have the smallest diameter possible while still allowing for just over 1 inch of deflection.

	55	Dia @ 55	Est. Steps
M4) 10.1lb	0.75	0.525	2126
M7) 10.1lb	1.00	0.52	1807
M7) 7.51lb	1.03	0.52	1815

- Length = 6in
- Width = ½in sleeving
- Force =
- Strain Capacity =
- Operating Pressure = 55psi
- Plug and fitting specs = brainstorming session 11/10/2014 results and CAD to follow
- Tank selection table:

Next Steps

1. Potentially purchase smaller silicon tubing to decrease the initial deflection of the single weave pink sleeving and iterate test once again.
2. Construct final 6" muscle with orange sleeving for integrated testing of the prototype going forward.