Product Development of a Resistive Athletic Suit

by

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SUBMITTED TO THE DEPARTMENT OF MECHANICAL ENGINEERING IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF SCIENCE IN ENGINEERING

AT THE

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

JANUARY 2008

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Submitted to the Department of Mechanical Engineering
On January 28th, 2008 in partial fulfillment of the
Requirements for the Degree of Bachelor of Science in Engineering
As Recommended by the Department of Mechanical Engineering

ABSTRACT

A preliminary prototype of a new athletic apparel product uses resistive straps, integrated within a suit, to provide muscular resistance. This developing fitness product allows users to exercise both their upper and lower bodies through either a regimented workout or just with daily movements.

An athletic workout suit that can provide a full body workout by using elastic straps that resist bodily movements was developed, redesigned, and tested. This project had three components: A resistive band was selected after various material tests, the interaction between strap placements and muscle movement was clarified, and finally a solution to anchoring the bands to the suit in a user-friendly method while allowing the resistance to be adjusted was designed. This product now has the potential to increase the efficiency at which people exercise, provide alternatives to existing workouts, and encourage healthy lifestyle.

Thesis Advisor: Dr. Kim Blair
Title: Director, Sports Innovation at MIT
Introduction

The fitness industry is constantly innovating and looking for products that can provide effective exercises in an efficient and comfortable manner. There are millions of athletes in the United States who each spend hundreds of dollars on fitness related products. Each year new products are introduced into the market. Products that are able to become successful are able to innovate to meet the consumer’s needs.

The Body Gym is an athletic suit that is currently being developed into a new product by a start up company. This suit provides a resistance workout without the need for free weights or a separate piece of exercise equipment. The product achieves this by integrating elastic bands into the suit to provide resistance against various muscles. The elastic straps are placed in key locations within the suit to resist against specific movements. The suit is separated into two pieces and made of a tight-fitting synthetic fabric. The developers of this product hope it becomes a new standard in the fitness apparel industry.
Motivation and Background

The fitness industry is constantly expanding as consumers are looking for products that can provide an enjoyable workout that is effective and time-efficient. There is a large potential to develop very unique products specifically for elite athletes because of their desire for the most effective exercise. In addition to the elite athlete, the casual individual that sometimes lacks motivation to work out at a gym and is unwilling to buy bulky equipment for their homes would also benefit greatly from this product. It would enable them to workout without the need for a gym membership or expensive equipment in the home. The Body Gym may also appeal to other markets by providing an alternative or supplemental workout to the more devoted athlete.

The elite athlete is the primary customer for the first product offering. The product is being designed to handle regimented strength workouts and also to provide
resistance for daily movements. Once the product is proven to work with the elite athlete, this technology could then be incorporated into products targeted towards other markets including rehabilitation centers, the elderly and collegiate athletes.

The technology being integrated within the Body Gym is fairly common. There are many products that use elastic material for resistance training. The most closely related product to the Body Gym is Thera-band. Thera-bands are latex bands used most commonly in rehabilitative centers to strengthen muscles and tendons in athletes recovering from injury. One advantage of products that use elastics for strength training is that they are very light in weight but can still provide a large resistance.

![Thera-Band Exercising Tubing and Bands](image)

Figure 2. Thera-Band Exercising Tubing and Bands

While the Body Gym is not using innovative technology, it hopes to use this proven technology in a new and innovative way. By integrating elastic straps into an athletic suit, the Body Gym can offer alternative workouts to a variety of individuals.

The current Body Gym prototype was made in 1998 and subsequently patented in 2000 under U.S. Patent # 6,099,446.
There are, however, three key issues currently hindering the Body Gym’s ability to come to market:

- The resistive forces of the Body Gym need to be quantified and communicable to the customers.
- The strap locations need to increase the range of exercises in an effective and user-friendly manner because the current design has limited muscle exercise capability.
- The Body Gym needs a system that allows the straps to more easily anchor into the suit or body.

These three issues will be examined at length within this thesis.

Strap Material Selection; Testing

Introduction

A crucial element in developing the Body Gym is selecting the material to be used to provide resistance. The material must be elastic so that it can provide resistance when stretched but then revert to its initial position before the next repetition or movement takes place. The first step in the thesis project was to conduct a comparative analysis of various elastic materials. The initial prototype used pallet strapping to provide the resistance. This material was benchmarked against other elastics including Latex, Neoprene, Ethylene Propylene Diene Monomer (EPDM), and different sizes of generic pallet strapping. The benchmark materials were selected based on their cost, available sizes, and ability to withstand temperatures of at least 190°F due to the high temperature washing.
Method

Twelve elastic samples underwent tensile strength testing. The samples were tested in the TELAMS laboratory at MIT on an Instron testing machine.

![Image of rubber samples being tested](image)

**Figure 3 Rubber Samples about to be Tested**

Each of these samples were stretched approximately 3" and the corresponding forces required to pull them were recorded. Each sample was tested at 3 different stretching rates: 0.33" per second, 1" per second, and 2" per second. These stretching rates were chosen because they will correspond to the rates the elastic bands are stretched during the specific exercises. Stretching the elastic at faster rates will require more force to displace it than if it had been stretched at a slower rate.
The 3” displacements were in the elastic region of all these samples. The rubber materials have a non-linear stress-strain relationship. As a result, the stress-strain relationship beyond the tested displacement should not be inferred through a linear regression, but instead interpolated through a polynomial regression. For each of the test trials, the force and corresponding position of the clamp were recorded as the band was stretched. From the position, the displacement of the elastic band was calculated and graphed against the corresponding force within Microsoft Excel.
Results

Below, in Figure 5, a sample of the test results is graphed. Appendices 1 – 12 are the graph results of all the tests.

Figure 5. Sample Tensile Strength Testing Data
The displacement load data from figure 5 was used to create Table 1, which shows the expected resistance during a typical exercise. In most uses of the Body Gym, the elastic band will be pre-stretched to a certain resistance level, which can be read across the top of the table. Each exercise motion will then increase the displacement of the band further than this initial pre-stretched distance. This displacement is read down the vertical direction in the table. The table informs the user how much resistance will result from the combination of pre-stretching and undergoing the exercise movements. For example, if a band was pre-stretched 5” and a bicep curl stretched the bands 2”, the user would look across the top row for 5”, move downwards until the 2” row, and read that load for this exercise was 18 lbs. A complete table for the 0.75” pallet strapping can be found in Appendix 13.

Table 1. 0.75” Pallet Strapping Load (lbs) for a 5” Pre Stretch and 2” Displacement

<table>
<thead>
<tr>
<th>Pre- Stretched (in)</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.2</td>
<td>6.5</td>
<td>8.8</td>
<td>11.1</td>
<td>13.4</td>
<td>▼</td>
<td>18.0</td>
<td>20.3</td>
<td>22.6</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>▼</td>
<td>18.0</td>
<td>20.3</td>
<td>22.6</td>
</tr>
<tr>
<td>3</td>
<td>8.8</td>
<td>11.1</td>
<td>13.4</td>
<td>15.7</td>
<td>18.0</td>
<td>20.3</td>
<td>22.6</td>
<td>24.9</td>
<td>27.1</td>
</tr>
<tr>
<td>4</td>
<td>11.1</td>
<td>13.4</td>
<td>15.7</td>
<td>18.0</td>
<td>20.3</td>
<td>22.6</td>
<td>24.9</td>
<td>27.1</td>
<td>29.4</td>
</tr>
<tr>
<td>5</td>
<td>13.4</td>
<td>15.7</td>
<td>18.0</td>
<td>20.3</td>
<td>22.6</td>
<td>24.9</td>
<td>27.1</td>
<td>29.4</td>
<td>31.7</td>
</tr>
<tr>
<td>6</td>
<td>15.7</td>
<td>18.0</td>
<td>20.3</td>
<td>22.6</td>
<td>24.9</td>
<td>27.1</td>
<td>29.4</td>
<td>31.7</td>
<td>34.0</td>
</tr>
<tr>
<td>7</td>
<td>18.0</td>
<td>20.3</td>
<td>22.6</td>
<td>24.9</td>
<td>27.1</td>
<td>29.4</td>
<td>31.7</td>
<td>34.0</td>
<td>36.3</td>
</tr>
<tr>
<td>8</td>
<td>20.3</td>
<td>22.6</td>
<td>24.9</td>
<td>27.1</td>
<td>29.4</td>
<td>31.7</td>
<td>34.0</td>
<td>36.3</td>
<td>38.6</td>
</tr>
<tr>
<td>9</td>
<td>22.6</td>
<td>24.9</td>
<td>27.1</td>
<td>29.4</td>
<td>31.7</td>
<td>34.0</td>
<td>36.3</td>
<td>38.6</td>
<td>40.9</td>
</tr>
<tr>
<td>10</td>
<td>24.9</td>
<td>27.1</td>
<td>29.4</td>
<td>31.7</td>
<td>34.0</td>
<td>36.3</td>
<td>38.6</td>
<td>40.9</td>
<td>43.2</td>
</tr>
</tbody>
</table>
Table 2. Material Specifications and Strength at 2.5" of displacement

<table>
<thead>
<tr>
<th>Material</th>
<th>Width</th>
<th>Thickness</th>
<th>Force (lbs) to Stretch 2.5&quot; at 0.33&quot;/sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neoprene</td>
<td>2&quot;</td>
<td>0.125</td>
<td>36</td>
</tr>
<tr>
<td>Neoprene</td>
<td>1&quot;</td>
<td>0.125</td>
<td>19.1</td>
</tr>
<tr>
<td>Neoprene</td>
<td>2&quot;</td>
<td>0.0625</td>
<td>16.2</td>
</tr>
<tr>
<td>Neoprene</td>
<td>1&quot;</td>
<td>0.0625</td>
<td>8.2</td>
</tr>
<tr>
<td>Tapered Neoprene</td>
<td>2&quot; - 1.1&quot;</td>
<td>0.0625</td>
<td>11.1</td>
</tr>
<tr>
<td>Tapered Neoprene</td>
<td>2&quot; - .65&quot;</td>
<td>0.125</td>
<td>15.74</td>
</tr>
<tr>
<td>Pallet Strapping</td>
<td>.775&quot;</td>
<td>0.125</td>
<td>7.85</td>
</tr>
<tr>
<td>Pallet Strapping</td>
<td>0.55&quot;</td>
<td>0.125</td>
<td>5.06</td>
</tr>
<tr>
<td>Pallet Strapping</td>
<td>0.3&quot;</td>
<td>0.125</td>
<td>2.72</td>
</tr>
<tr>
<td>Latex</td>
<td>2&quot;</td>
<td>0.125</td>
<td>14.8</td>
</tr>
<tr>
<td>Beemis</td>
<td>2&quot;</td>
<td>0.01</td>
<td>8.1</td>
</tr>
<tr>
<td>EPDM</td>
<td>3/4&quot;</td>
<td>0.225</td>
<td>26</td>
</tr>
</tbody>
</table>

The next prototype of the Body Gym will need a selected elastic material to form the resistive bands. The developers of this product would like the bands to be capable of providing a range of resistances for each of the exercises. To meet this need, various geometries of elastic bands maybe needed to create the appropriate resistance. As seen in the table above, varying geometries give drastically different resistances when either the width or thickness is changed.

Conclusion

At the present time, though, a recommendation was made to continue using the pallet strapping for prototypes, however the final prototype may use a different elastic material based on unforeseen restrictions. This decision to use pallet strapping was made because the strength of this material matches the preliminary resistance range desired by the developers for given displacements and it is considerably cheaper than the similar materials. In order to provide specific dimensions for each of the straps, the desired resistance ranges need to be altered after a more detailed market and customer analysis.
takes place. These material testing results will serve as a reference and provide useful information to potential investors until the manufacturer and supplier of elastics are selected. Future tests on the selected material will need to take place to further determine the stress-strain relationship, its fracture point, and its mean time to failure.

Strap Design and Placement

The second critical component of this project was to place the bands in optimal locations to provide the most effective resistance and seamless integration to a consumer product. The first step in this process was to map out the human body and match band placements to muscles that they will exercise.

The current prototype has two main types of bands. The first band runs from the palm to the back side of the elbow, to the shoulder blade, across the back and then down the mirror image on the other arm. The bands are held in place along the elbows and shoulder blades. This band is capable of exercising muscles within the chest, shoulders, and the biceps. The second type of band runs from hip along the outside of the leg to the ankle where it loops around and fastens on the inside of the calf. The band is secured along the outside of the knee.

The design strategy used to position the straps followed the process of Functional Requirements, Design Parameters, Analysis, References, Risks, and Countermeasures (FRDPARCC). The FRDPARCC design strategy is taught and commonly used in the introductory manufacturing and design class at the Massachusetts Institute of Technology.
**Functional Requirements**

The straps within the Body Gym suit must provide resistance to various muscles within the body when specific body movements are made. The bands, however, must not impede normal movements and must be adjustable.

**Design Parameters**

The bands must be capable of being attached to specific areas within the suit to create a seamless product.

**Analysis**

The decision to use a specific band will be based upon user feedback testing and manufacturability.

**References**

Strap locations will reference the Thera-band exercise guide as well as common exercises. The placement of the bands will mirror the resistance vectors various Thera-band exercises and free weight motions.

**Risks**

The strap locations may not function properly with individuals of different body proportions.

**Countermeasures**
The suit could have multiple sizes or be tailored to function optimally.

**Conclusion and Recommendations**

After receiving feedback from four males between the ages of 18 and 22, who tested the original suit, it was decided that more straps needed to be integrated into the suit to provide a fuller body workout. They noted that they would like the suit to provide resistance against their quadriceps, hamstrings, abdomen, shoulders, and pectorals.

After considering the natural motions of the human body, a variety of suggestions for strap placements were made. In the table below the suggested straps are listed with the corresponding muscles that are exercised. The bolded straps are the new additions to the suit.

Table 3. Strap Placements

<table>
<thead>
<tr>
<th>Strap</th>
<th>Attachments</th>
<th>Muscle Exercised</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arm Strap</td>
<td>Wrist and Shoulder</td>
<td>Bicep, Forearm</td>
</tr>
<tr>
<td>Top of the Back</td>
<td>Shoulder to Shoulder</td>
<td>Chest</td>
</tr>
<tr>
<td>Underarm</td>
<td>Along Armpit</td>
<td>Shoulder</td>
</tr>
<tr>
<td>Back</td>
<td>Shoulder to Opposite Hip</td>
<td>Abdomen, Lats</td>
</tr>
<tr>
<td>IT Band</td>
<td>Hip to Ankle</td>
<td>Quadriceps, Hamstrings, Groin</td>
</tr>
<tr>
<td>Quadriceps</td>
<td>Waist to Knee</td>
<td>Hamstrings, Gluteus</td>
</tr>
<tr>
<td>Hamstring</td>
<td>Waist to Back of Knee</td>
<td>Quadriceps, Hip Flexor</td>
</tr>
</tbody>
</table>
Below is a visual representation of the both the old and new strap locations integrated into the Body Gym suit.

Figure 6 Front of the Top

Figure 7 Front of the Bottom
Because the Body Gym is a retail apparel product, the aesthetics of the design are also important. A key decision concerning the construction and appearance of the suit.
will be the exposure of the elastic bands. The bands may be entirely enclosed by a tight fitting material, slightly opened by a mesh material, or be fully exposed. If the bands are enclosed over a large length, they might become caught on fabric and cause a disjointed movement.

**Integration Point Design**

The last component of the project was to make design recommendations for the wrist, ankle, and waist attachment points. The initial prototype design for the wrist forced the user to hold the bands in his hands and created a limited exercise experience. The ankle currently had the band extending beyond the cuff where it forms a loop before being wrapped around to the other side of the cuff. The waist line of the pants was an oversized piece of material that was sewn into the fabric. The elastic band along the side of the body was secured by a webbing strap. The design challenge was to provide an ergonomic and efficient attachment process that allows the resistive band’s length to be adjusted while ensure it is anchored to the suit or person. The bands need to be adjustable to continually meet the fitness needs of the athlete. There needs to be an easy transition from a regimented workout with high resistance to a more passive workout with lower resistance. The attachment points are critical in creating a seamless product whose simplicity does not jeopardize the functionality of the exercise suit.
For these design challenges, a brainstorming and concept generation process first took place. The FRDPARCC design strategy was also used in this section. Several mockup experiments were conducted and opinions of individuals testing the initial prototype were used in developing the designs. Once the design solutions were selected, they were then forwarded to the company who would bring the materials into a professional manufacturer to begin the process of constructing the next prototype.

**Wrist Attachment Point**

*Functional Requirements*

The wrist is an important point in the Body Gym. The main arm strap, which runs behind the tricep, around the elbow and into the wrist, needs to be fastened securely while still allowing for adjustments to be made. In the original prototype, the user adjusted the resistance of the elastic strap by pulling the strap to the desired resistance and then wrapping the excess around the palm, and finally clenching his fist to secure the band in place. This process could be done with or without gloves. A key problem in this
prototype was that the user's hands always needed to be clenched. One of the individuals in the feedback trials noted that it felt natural to exercise with your fist clenched. Taking this into consideration, two designs solutions engage the palm of the user, but require the use of gloves. A third design solution allows the elastic strap to be secured before the band reaches the hand while still allowing for adjustability.

*Design Parameters*

The simplicity of the design is very important. The elastic band should be easily adjustable and the design should allow for the forearm to be exercised.

*Analysis*

The design solutions will be analyzed through mock up models and user-testing.

*References*

When examining similar products with the need for adjustability around the wrist, it was noticed that Velcro was the most commonly used method. The Nike Dri Fit gloves use a Velcro strap that wraps over the wrist towards the inside of the arm.
Risks

There are several design risks for the wrist attachment point. One is the bands interfering with the user’s ability to manipulate objects with his hands.

Countermeasures

The palm of the glove can be designed using thin material and allowing the fingers to be free to move.

Conclusion and Recommendations

In order to integrate this technology into the Body Gym, the elastic bands could either be secured by the strapping force or the bands could have Velcro sewn into one of the sides. The use of buttons, clasps, clips, or webbing fasteners all provide feasible methods of securing the band; however they become increasingly difficult to adjust on the user’s dominate hand because it requires the non-dominate hand to perform a skilled
movement. Velcro is a very versatile material and does not require as careful of coordination as the other fasteners.

In the first design solution the band runs through the palm, around the top of the hand, and then back towards the palm where it is then secured by a Velcro strap. This direct route into the wrist gives moderate resistance for the forearm. In addition the elastic band is overlapped along the palm of the user which may cause discomfort or interfere with the ability to grab items.

![Figure 12 Securing Bands in Design 1](image)

A second solution is flexible to either incorporate a glove or to rely solely on the cuff at the end of the arm. In this design, the band will wrap around from the elbow and as it approaches the wrist will pass through several clips, either part of a glove or cuff. The band would then flipped backwards after the clip and be fastened by a Velcro strap.
This design is relatively simple and could be used without separate gloves. However this design, does not engage the user as much as previous design. The location in which the band is secured also does not provide much forearm resistance.

The third design solution is similar to the first design except the elastic band is directed from the elbow diagonally across the forearm towards the thumb and the pointer finger. On the back of the hand there is a channel with a Velcro bottom that guides the band.

After being placed at the appropriate resistance in the channel, the band then wraps along the palm towards the outside of the hand where it then wraps back to the top of the hand. The band is then secured by a Velcro strap very similar to that of the Nike Dri fit glove. This design allows the user to clench their hands along the band and feel resistance within the hands. However, the user will still have the freedom to open his hands with out the bands loosening as it was in the initial prototype.
Below is a four-step picture showing how a user would fasten the band onto the left hand using this design solution.

Figure 14 Securing Band for the 3rd Design
A recommendation of using this last solution was made. It will provide a secure hold on the elastic bands and allow the resistance to be adjusted easily. The glove used should incorporate various designs included in other successful products so it does not differ much from the current standards.

**Ankle Attachment Point**

The current integration point for the ankle of the initial prototype has the elastic band run underneath the heel. The inventor of the Body Gym describes that band as forcing the user onto his toes which engages various muscles within the lower leg such as the calf. According to the user feedback, the current design was somewhat uncomfortable within the shoe. In addition, some noted that their foot would get caught while trying to enter the band loop. This design for anchoring the suit appeared flimsy and unpolished.

*Functional Requirements*

The key requirements for the ankle attachment point were securing the band that runs along the outside of the leg in easy manner and maintaining resistance for the calf muscle.

*Design Parameters*

The simplicity of the design is very important. The elastic band should be easily adjustable and the design should allow for the calf to be exercised.

*Analysis*

The design solutions will be analyzed through mock up models and user-testing.
References

Potential ankle attachment design solutions are similar to ankle protectors used in soccer. In addition, Dr. Scholl’s heel inserts are representative of one piece in a design solution.

![Ankle Protectors](image)

Figure 15 Ankle Protectors

Risks

One risk the Body Gym faces is that the ankle attachment may be bulky and cause discomfort for the users. Another risk is that the attachment method may slip within the shoe.

Countermeasures

To address this concern, the design must be as sleek as possible.

Conclusion and Recommendations

Several design concepts incorporated an ankle brace that would allow the elastic bands to snap into the brace via a type of fastener or clasp. It was determined that this would be too time consuming to put on and secure for each use. One other conceptual
solution was to integrate clips or fasteners into a sneaker where the bands would then attach. After discussions with the developers, it was decided that the use of separate items for the ankle attachments would complicate the product and seriously affect its usability. With instructions to minimize the complexity regarding the ankle attachment, the original design deserved a second-look.

The Body Gym would need to address both the comfort and accessibility of entering and exiting. By sewing a smooth fabric on the inside of the band, the foot would be less likely to get caught. In addition, this fabric could be shaped such that it provides a more comfortable feel for the user.

![Figure 16 Outside Profile View of Heel Strap](image-url)
As the band wraps around the heel, the band will be guided along the inside of the ankle. From here, it will be attached above the cuff in a pre-stretched amount that will be determined in future prototype. Around the entire cuff, the pants must have a thicker fabric that encloses and secures the band as it enters the ankle region on both sides of the leg. This fabric will also help diminish the wear and tear on the suit.

**Other attachment points**

The waist band is the last major attachment region within the Body Gym. The waist band will anchor a total of six bands: two bands that run along the IT bands, two bands along the hamstrings, and two bands along the quadriceps. Each of these bands needs to be comfortable for the user and be adjustable. The waist band must also have some adjustability to accommodate varying waist sizes.
Functional Requirements

The bands along the quadriceps and hamstring are intended to be more permanent. These bands must be secured in a manner that does not cause discomfort. The bands along the IT band must be secured but allow for more adjustability.

Design Parameters

The simplicity of the design is very important. The elastic band should be easily adjustable and the design should allow for the calf to be exercised.

Analysis

The design solutions will be analyzed through mock up models and user-testing.

References

The straps on a backpack are very comparable to the IT band straps because they need adjustability and are located in similar locations of the body.

Risks

The main risk for the waist band attachments is that the bands cause discomfort along the hips of the user.
Countermeasures

To address this concern, the waist lines in the designs may need extra supportive fabric to cushion the user.

Conclusions and Recommendations

The quadriceps and hamstrings straps were decided to be attached via Velcro along the top of the band. The bottom section will be attached in a permanent method by sewing the straps tightly into the suit.

Figure 18. Generic Velcro

The bands along the side however are expected to be adjusted more frequently than the front. In addition, they need to handle more force. The webbing straps will be anchored to the suit by a fabric that loops through one buckle and is sewn into the suit, as seen in figure 19.

Figure 19 Webbing Strap and Anchored Band
The two straps secured via the webbing clips also serve a dual purpose. The excess strap material can be grabbed by the hands and used to do a variety of exercises in addition to the ones allowed solely by the bands integrated into the suit. For example the excess strapping can be used to exercise muscles in the shoulder and chest as seen in the figures below.

![Figure 20. Exercises using excess strapping](image)

**Conclusions**

The Body Gym is an innovative product that uses elastic straps integrated within a suit to provide muscular resistance. In order to move forward as product, the initial prototype needed the optimal band to be chosen, it needed to clarify the interaction between various straps and the muscles they exercised, and it finally needed attachment points to be redesigned in the suit. Pallet strapping was selected as the material for the elastic bands for future prototypes after a comparative analysis among fourteen rubber samples took place. The second step in the project suggested new strap locations to provide a fuller work-out experience. The last step in the project redesigned the ankle, wrist, and waistline attachment points with simplicity and reliability in mind.
Appendix 1.

Pallet Strap .75in (.33in/sec)

\[ y = 0.1647x^2 - 1.0959x^2 + 4.5954x + 0.4516 \]
2.

Pallet Strap _0.5 in (.33 in/sec)

\[ y = 0.1209x^3 - 0.8104x^2 + 3.2444x + 0.075 \]

3.

Pallet Strap _0.25 in (.33 in/sec)

\[ y = 0.068x^3 - 0.4525x^2 + 1.7509x + 0.019 \]
4. Neoprene 1in x .125in (.33 in/sec)

\[ y = 0.6834x^3 - 3.767x^2 + 11.734x + 2.6435 \]

5. Neoprene_1in_x_0.0625in (.33in/sec)

\[ y = 0.7723x^3 - 4.3885x^2 + 12.842x - 0.5333 \]
6. Neoprene 2in x 0.0625in (0.33in/sec)

\[ y = 2.3502x + 2.6813 \]

7. Neoprene 2in x 0.125 (.33in/sec)

\[ y = 2.4622x^3 - 12.961x^2 + 31.355x \]
8. Beemis .33 in /sec

\[ y = 0.2667x^3 - 1.5913x^2 + 5.4382x + 0.3642 \]

9. Latex (.33in/sec)

\[ y = 0.2001x^3 - 1.9636x^2 + 9.5058x + 0.1465 \]
10. EPDM (.33in/sec)

\[ y = 2.6326x^3 - 11.683x^2 + 23.626x - 0.8573 \]

11. Tapered Neoprene 0.125in (.33in/sec)

\[ y = 1.1291x^3 - 5.1243x^2 + 11.938x + 0.4151 \]
Tapered Neoprene 2in 0.0625in (.33in/sec)

\[ y = 0.6502x^3 - 3.483x^2 + 8.9234x + 0.2954 \]

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<th>Load (lbs)</th>
<th>Pre-Stretched (in)</th>
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</table>
Acknowledgements

Dr. Kim Blair
Thesis Advisor
Director, Sports Innovation at MIT

Dexter Williams
Executive Vice President and COO, BodyGym

Greg Moore
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Derrick Johnson
Inventor and CEO, BodyGym

John Kane
Research Specialist, TELAMS

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