

EML4551-2

Senior Design Team 519: Secure Fit Football Undershirt

Paul Cunningham, Vivi Huynh, Sawyer O'Bryan,
Nicholas Palestrini, Morgan Sefcik

Paul Cunningham

Team Introduction



Morgan Sefcik
*Project Manager and
Design Engineer*



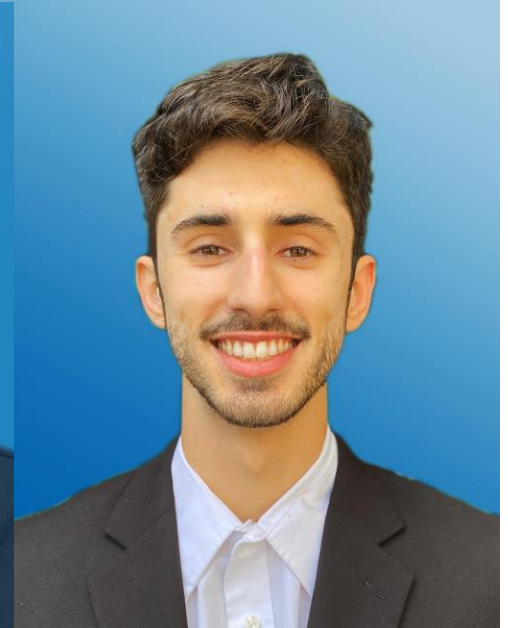
Paul Cunningham
*Design and Materials
Engineer*



Vivi Huynh
*Design and
Manufacturing
Engineer*



Sawyer O'Bryan
*Design and Materials
Engineer*



Nicholas Palestrini
*Product Development
and Data Engineer*

Paul Cunningham

Sponsor and Advisor



Sponsor
Mike Holloway
Survivor 30th Season Winner



Academic Advisor
Christian Hubicki, Ph.D.
Assistant Professor

Paul Cunningham

Project Objective

Reduce injury by increasing the effectiveness of shoulder pads

Paul Cunningham



Athletic Trainer Survey

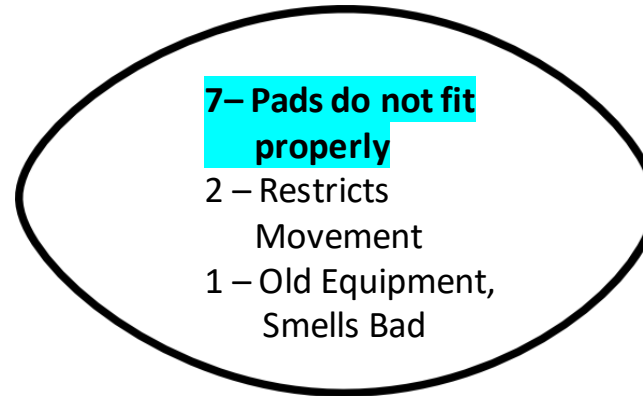
Responses

Key Questions

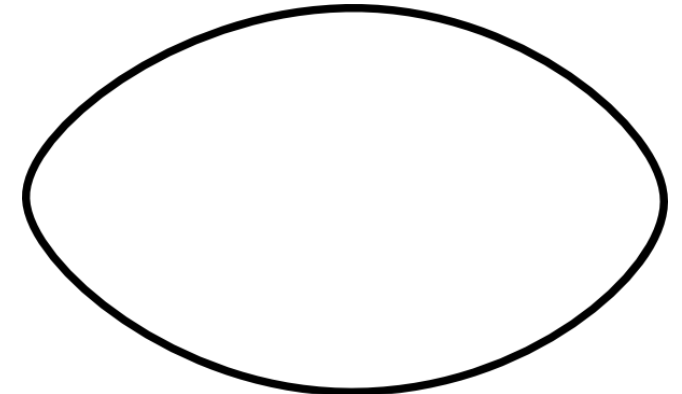
1. What are the Biggest Complaints about Shoulder Pads?

2. *Most Common blunt force injury?*

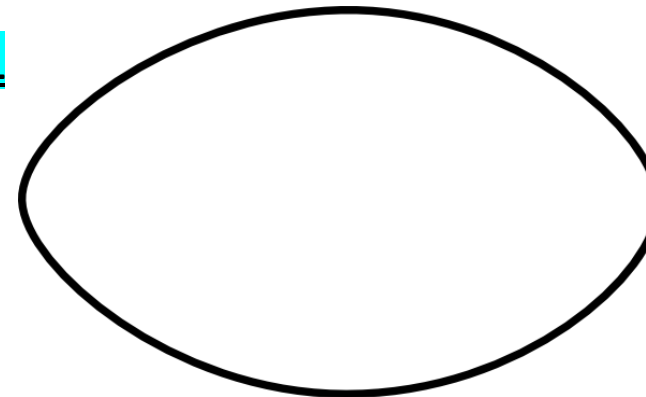
3. *Are there any protective materials that can be used to prevent contact injuries?*



Q1



Q2



Q3

Paul Cunningham

Athletic Trainer Survey

Responses

Key Questions

1. *What are the Biggest Complaints about Shoulder Pads?*

2. Most Common blunt force injury?

3. *Are there any protective materials that can be used to prevent contact injuries?*

7- Pads do not fit properly
2 - Restricts Movement
1 - Old Equipment, Smells Bad

Q1

5-Shoulder Related
3-AC Sprains
2-Concussions

Q2

Q3

Paul Cunningham

Athletic Trainer Survey

Responses

Key Questions

1. *What are the Biggest Complaints about Shoulder Pads?*

2. *Most Common blunt force injury?*

3. Are there any protective materials that can be used to prevent contact injuries?

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Q1

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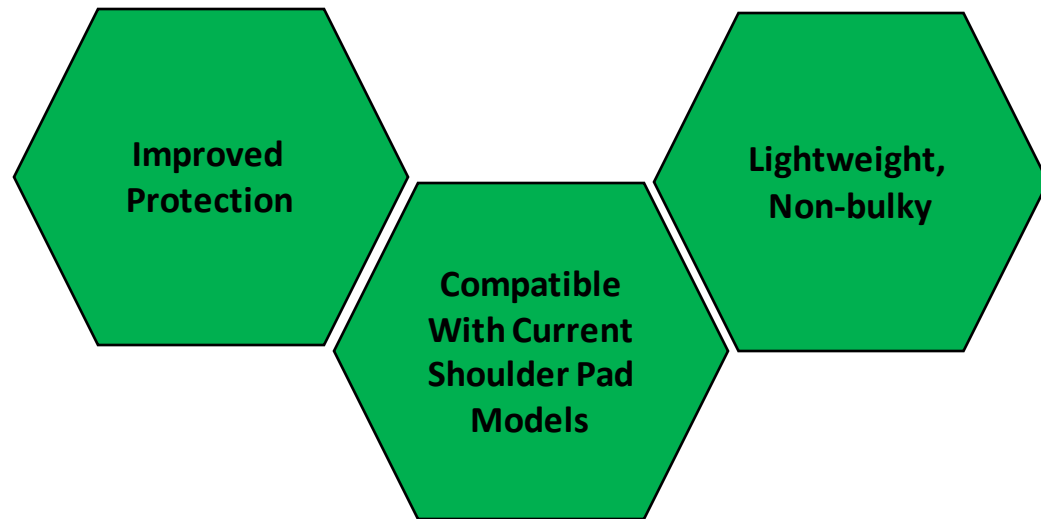
Q2

4 - Dense Cell Foam
2 - Kevlar
1 - Shoulder Shocks

Q3

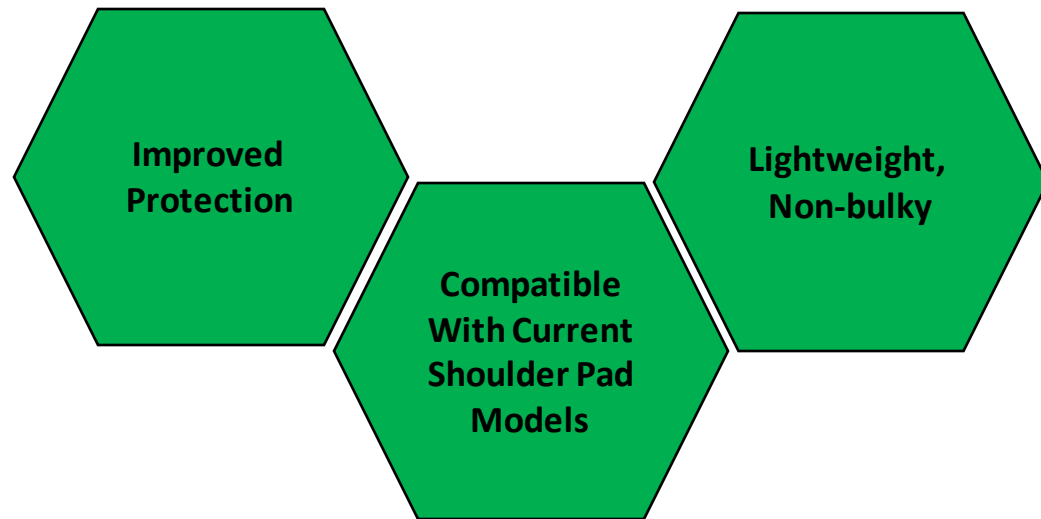
Paul Cunningham

Fundamental Needs

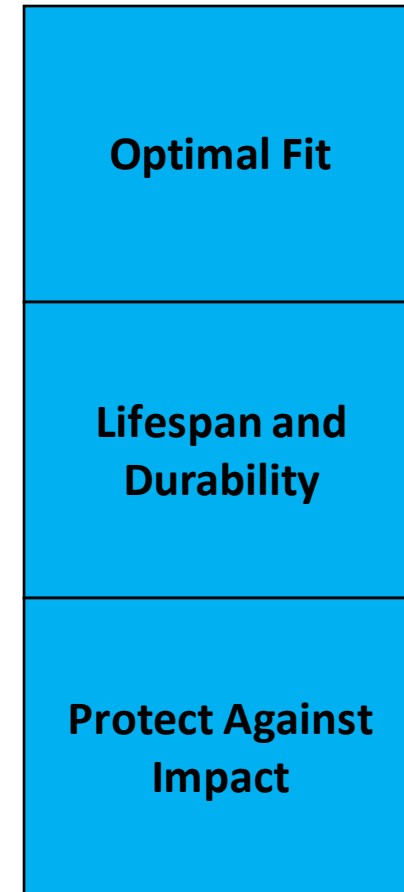


Paul Cunningham

Fundamental Needs



Key Goals



Paul Cunningham

Primary Functions

Protect

Form

Paul Cunningham

Secondary Functions

Protect

Absorb
Direct
Impact

Maintain
Shape

Form

Remains
Light
Weight

Adapts
to Fit

Paul Cunningham

Creating A Solution

Morgan Sefcik



Targets & Metrics

Function

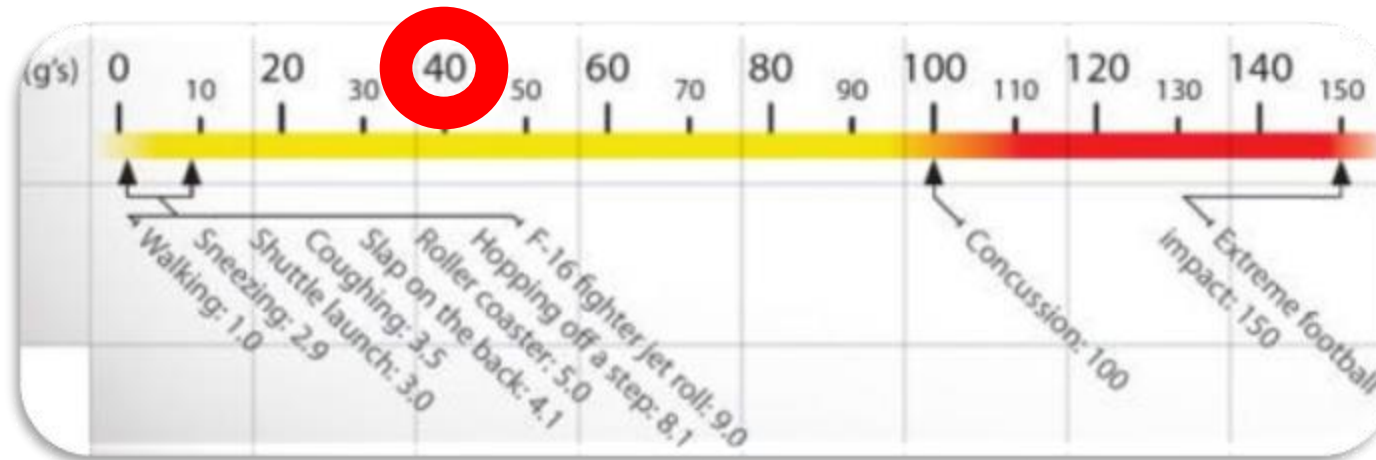
Absorb Direct Impact

Metric

Force (pound-force)

Target

Reduce Force by 75%



Morgan Sefcik

Targets & Metrics

Function

Absorb Direct Impact

Maintain Shape

Metric

Force (pound-force)

Volume (inches cubed)

Target

Reduce Force by 75%

No reduction in Volume



Morgan Sefcik

Targets & Metrics

Function

Absorb Direct Impact

Maintain Shape

Remains Lightweight

Metric

Force (pound-force)

Volume (inches cubed)

Weight (pounds)

Target

Reduce Force by 75%

No reduction in Volume

Less than 5 pounds

Morgan Sefcik

Targets & Metrics

Function

Absorb Direct Impact

Maintain Shape

Remains Lightweight

Adapts to Fit

Metric

Force (pound-force)

Volume (inches cubed)

Weight (pounds)

Motion (percent)

Target

Reduce Force by 75%

No reduction in Volume

Less than 5 pounds

30% reduction of
movement during contact

Morgan Sefcik

Concept Generation

Methods



Biomimicry



Morphological Chart



Crapshoot



Anti-Problem



Battle of Perspectives

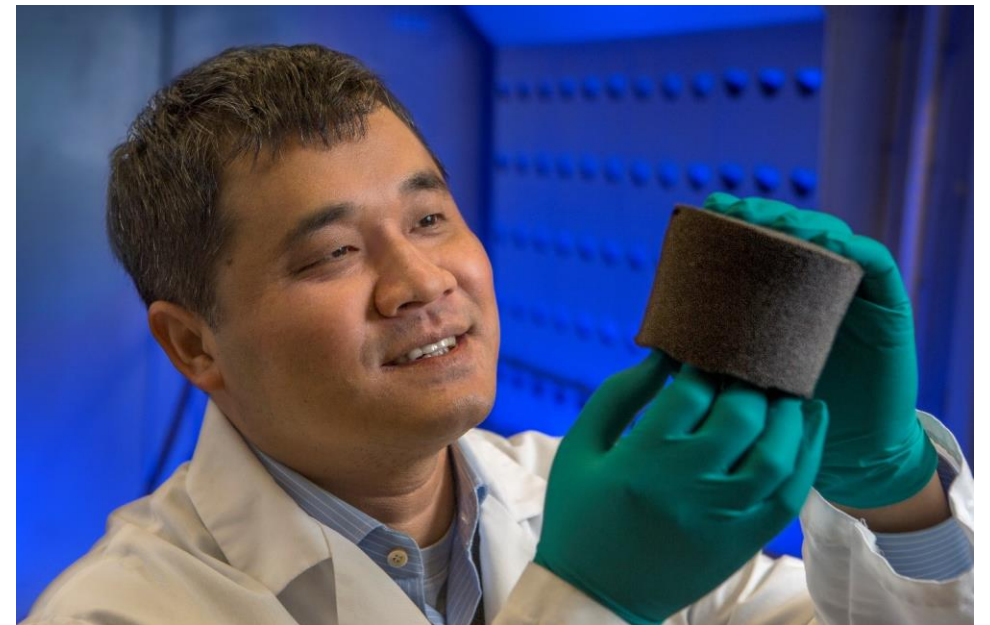


Brainstorming

Morgan Sefcik

First Selected Concept

Replace Interior Padding of Shoulder Pads with Auxetic Foam



Morgan Sefcik



Morgan Sefcik

Second Selected Concept

Undershirt that Improves Fit



Morgan Sefcik

Materials Testing

Nicholas Palestrini



Compression Test



Nicholas Palestrini

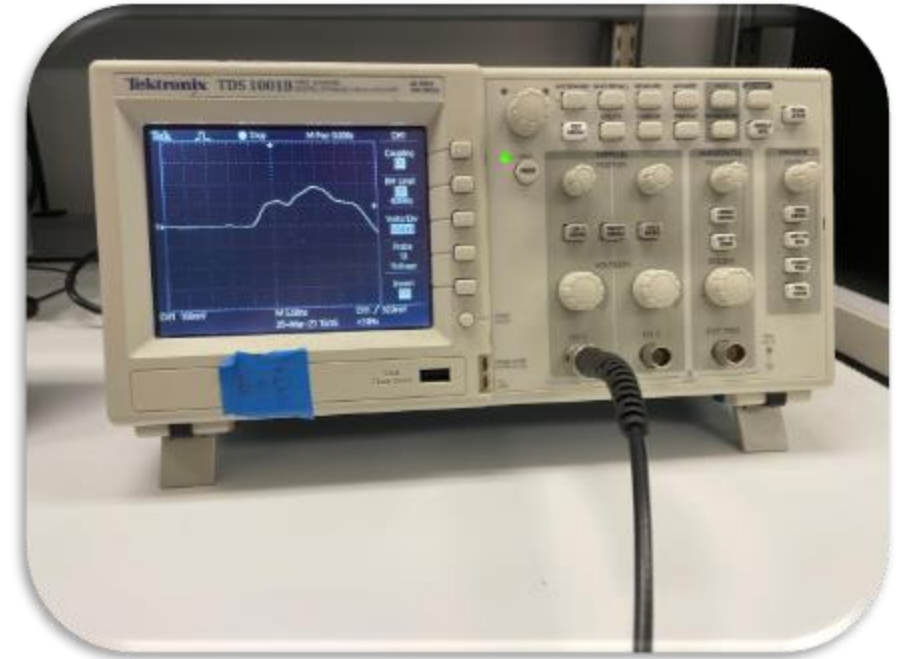
Compression Test Results

| Mean Percent Height Reduction | |
|---------------------------------|------------------|
| Polyurethane Foam | 0.0288 % |
| Polyimide Foam | 0.0400 % |
| Open-Cell Polyurethane Foam | 0.0745 % |
| Organic Latex Shredded Foam | 0.0867 % |
| Gel Shredded Memory Foam | -0.0207 % |



Nicholas Palestrini

Pendulum Impact Test



Nicholas Palestrini

Pendulum Impact Test Results

| Mean Percent Force Reduction | |
|------------------------------|-----------|
| Polyurethane Foam | 40.3954 % |
| Polyimide Foam | 28.3345 % |
| Open-Cell Polyurethane Foam | 20.8708% |
| Organic Latex Shredded Foam | 27.7816 % |
| Gel Shredded Memory Foam | 28.8874 % |



Nicholas Palestrini

Fit Optimization: Shoulder Mold



Nicholas Palestrini

Fit Optimization: Contact Points



Nicholas Palestrini

Designing the Undershirt

Vivi Huynh



Explored Concepts



Vivi Huynh

Explored Concepts

- Sealing tests (Heat Treatment)
- Stress tests (Popping Prevention)
- Implementation of channels



Vivi Huynh

Material Selection



1. HeatGear Compression Undershirt

2. Outside Pocket Fabric

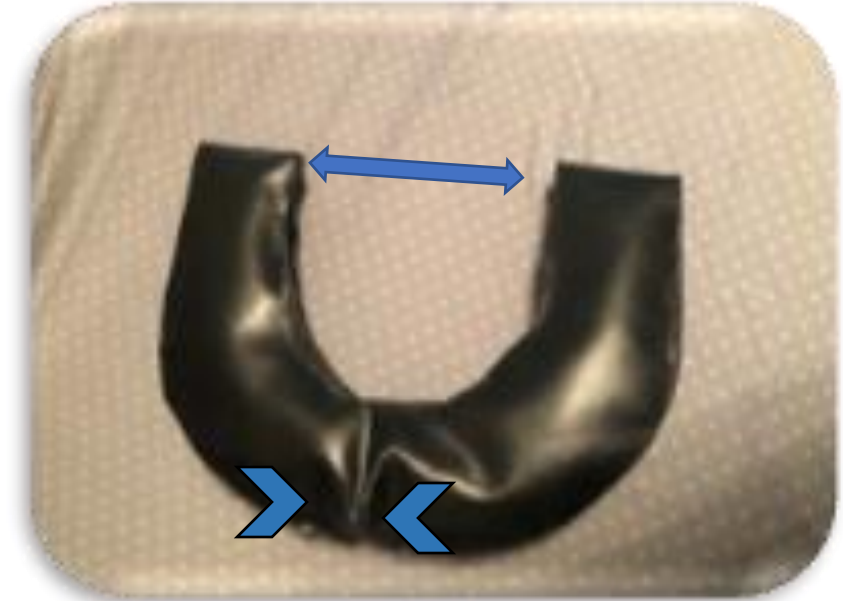
- Polyester Sweat Wicking fabric

3. Ultra-Weather Resistant Nylon Fabric Sheet

- Gel Memory Foam
- Polyurethane Foam

Vivi Huynh

Updated Prototype



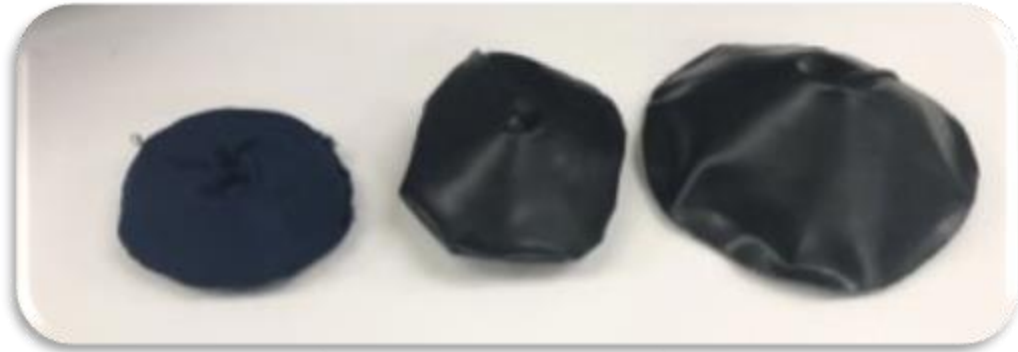
Vivi Huynh

Latest Prototype



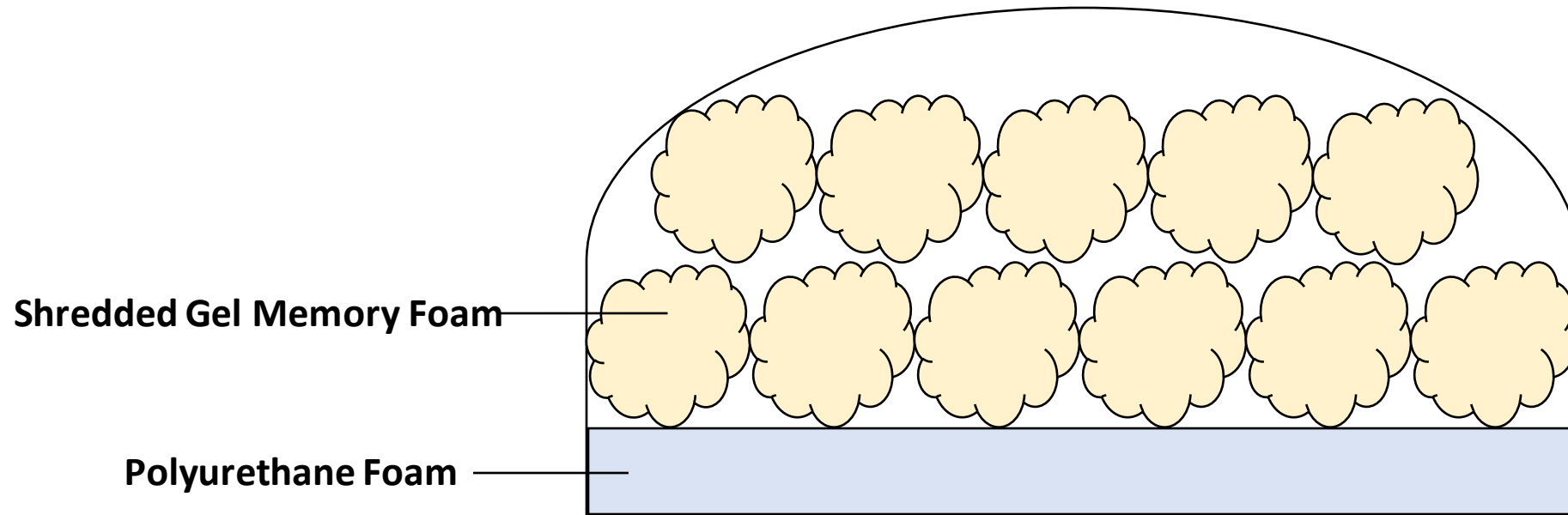
Vivi Huynh

Shoulder Pad Progression



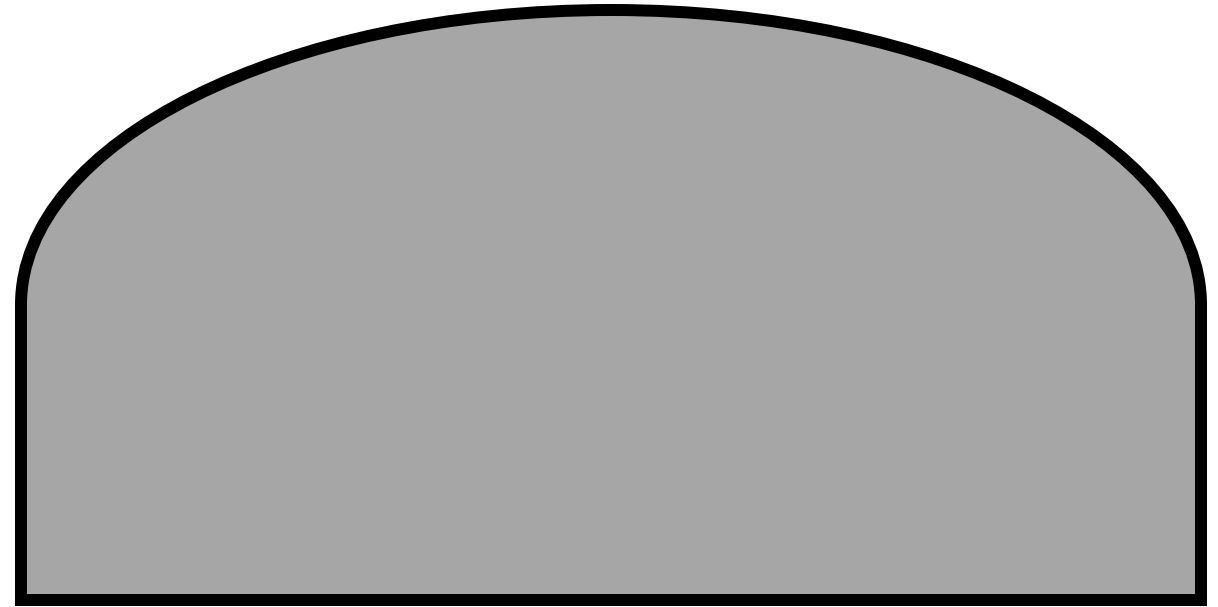
Vivi Huynh

Choice Of Foam



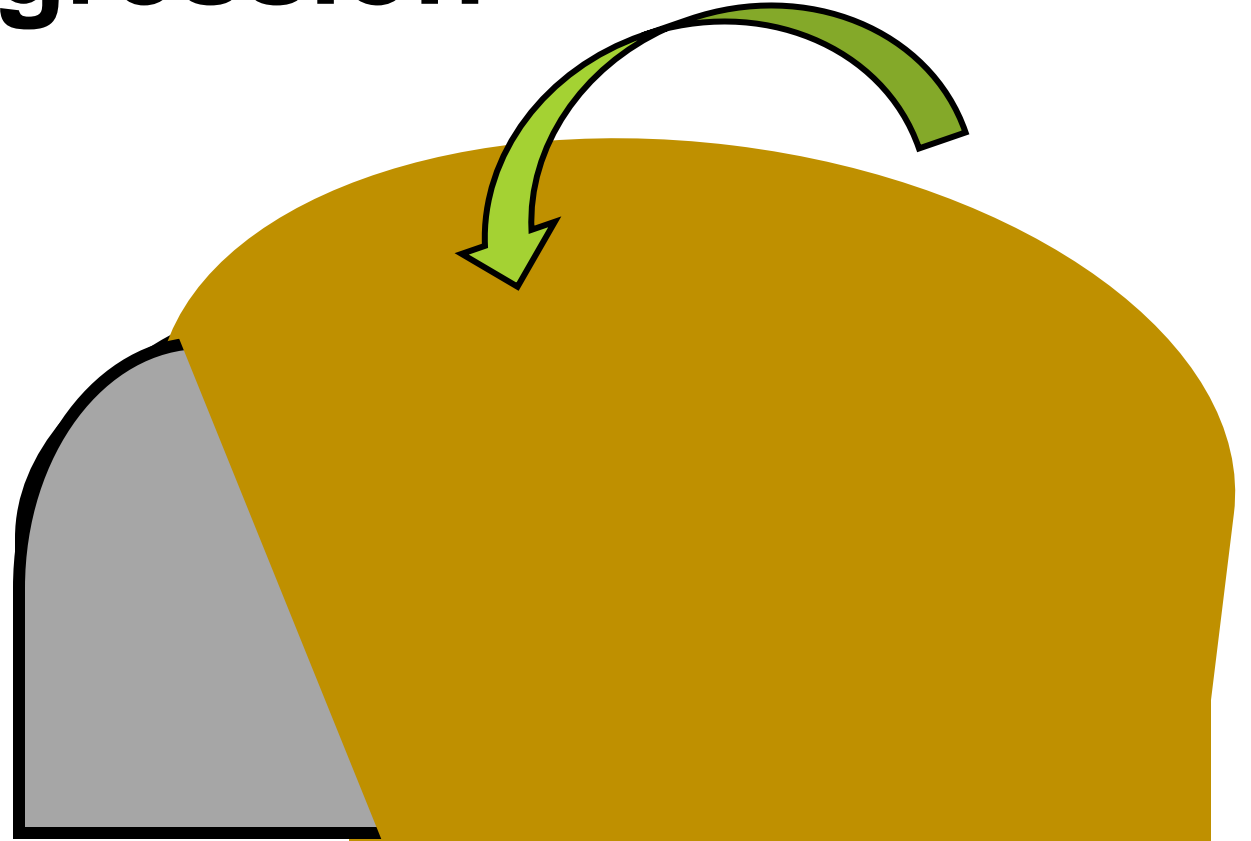
Vivi Huynh

Shoulder Pad Progression



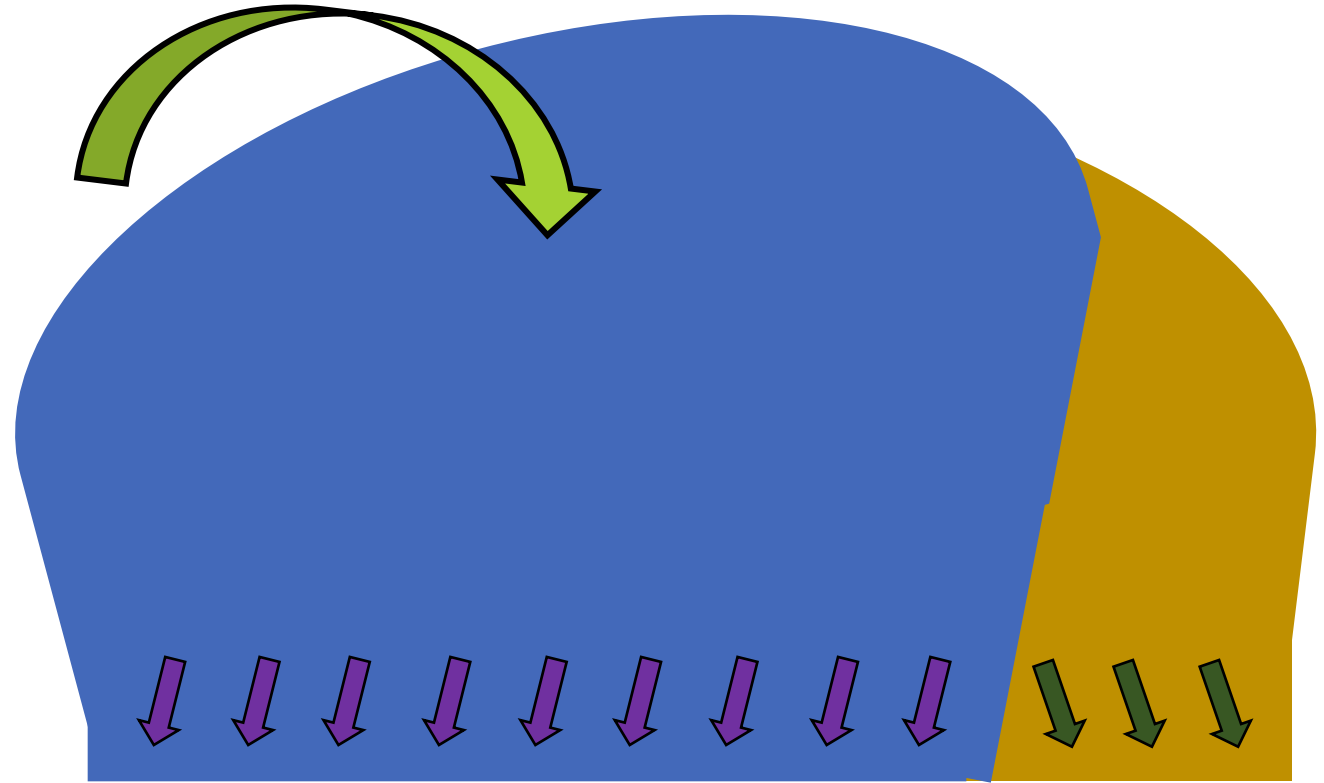
Vivi Huynh

Shoulder Pad Progression



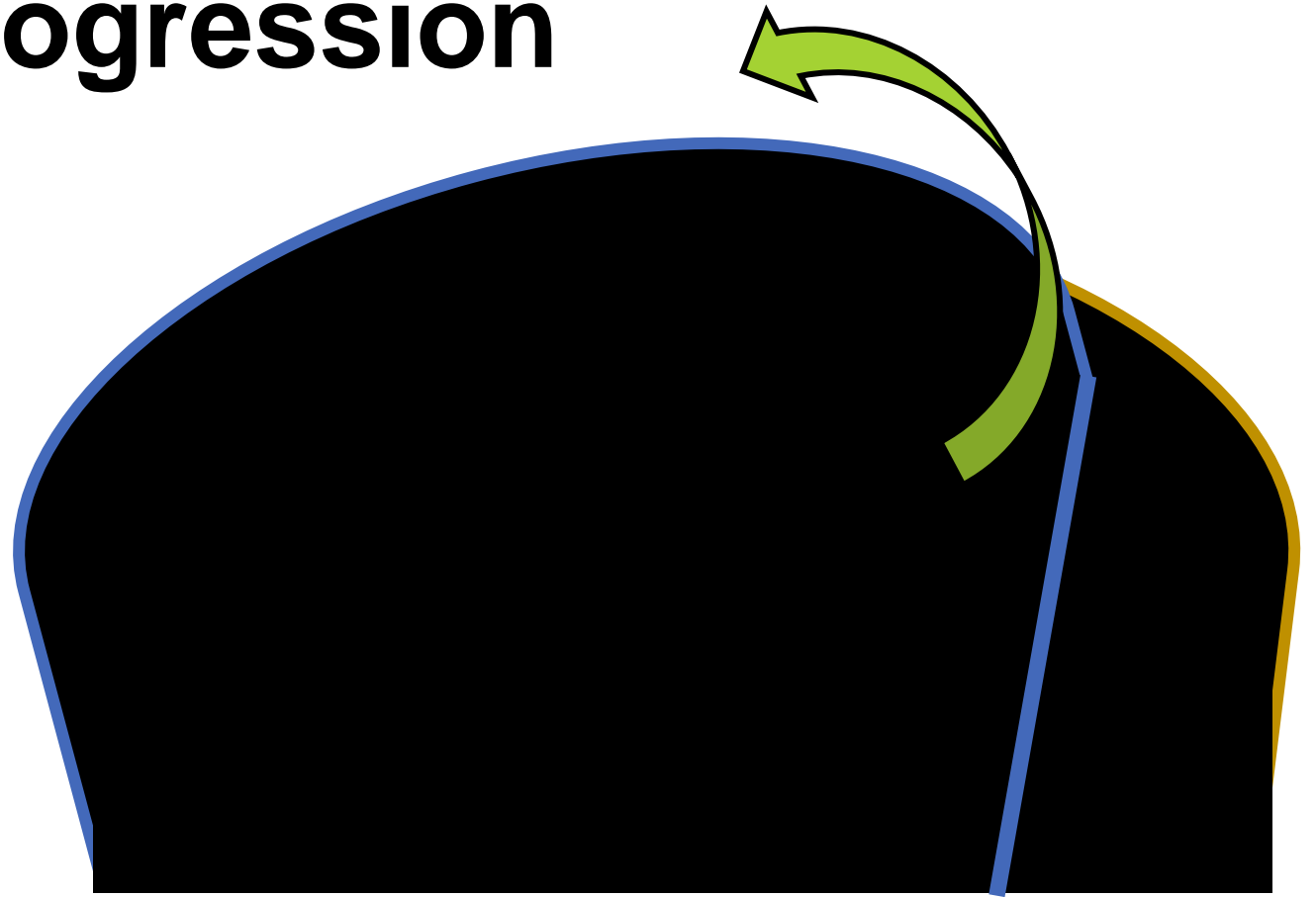
Vivi Huynh

Shoulder Pad Progression



Vivi Huynh

Shoulder Pad Progression



Vivi Huynh

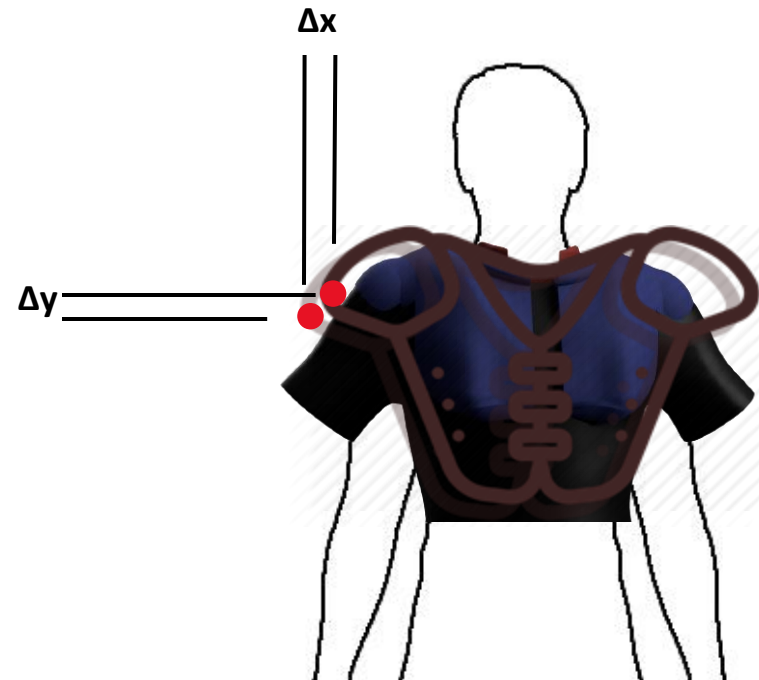
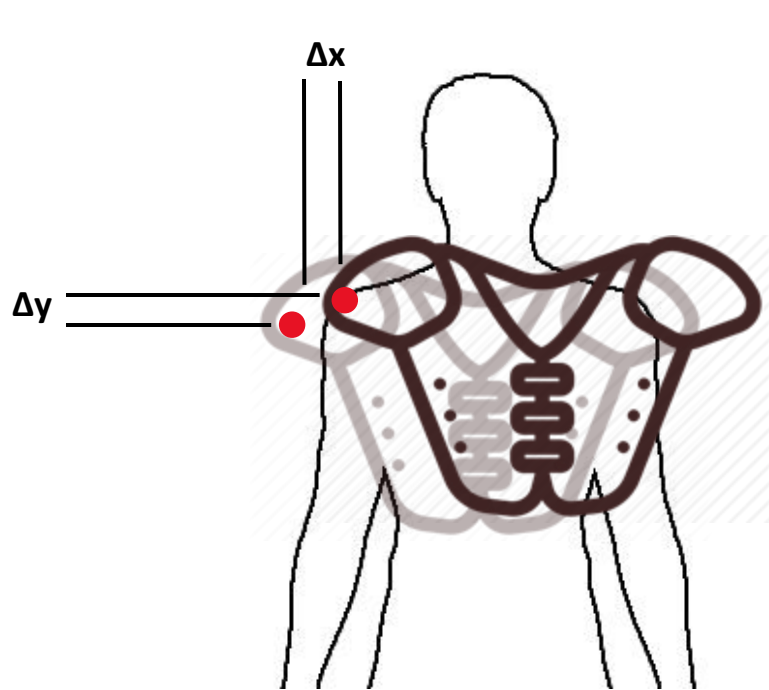
Undershirt Validation

Sawyer O'Bryan



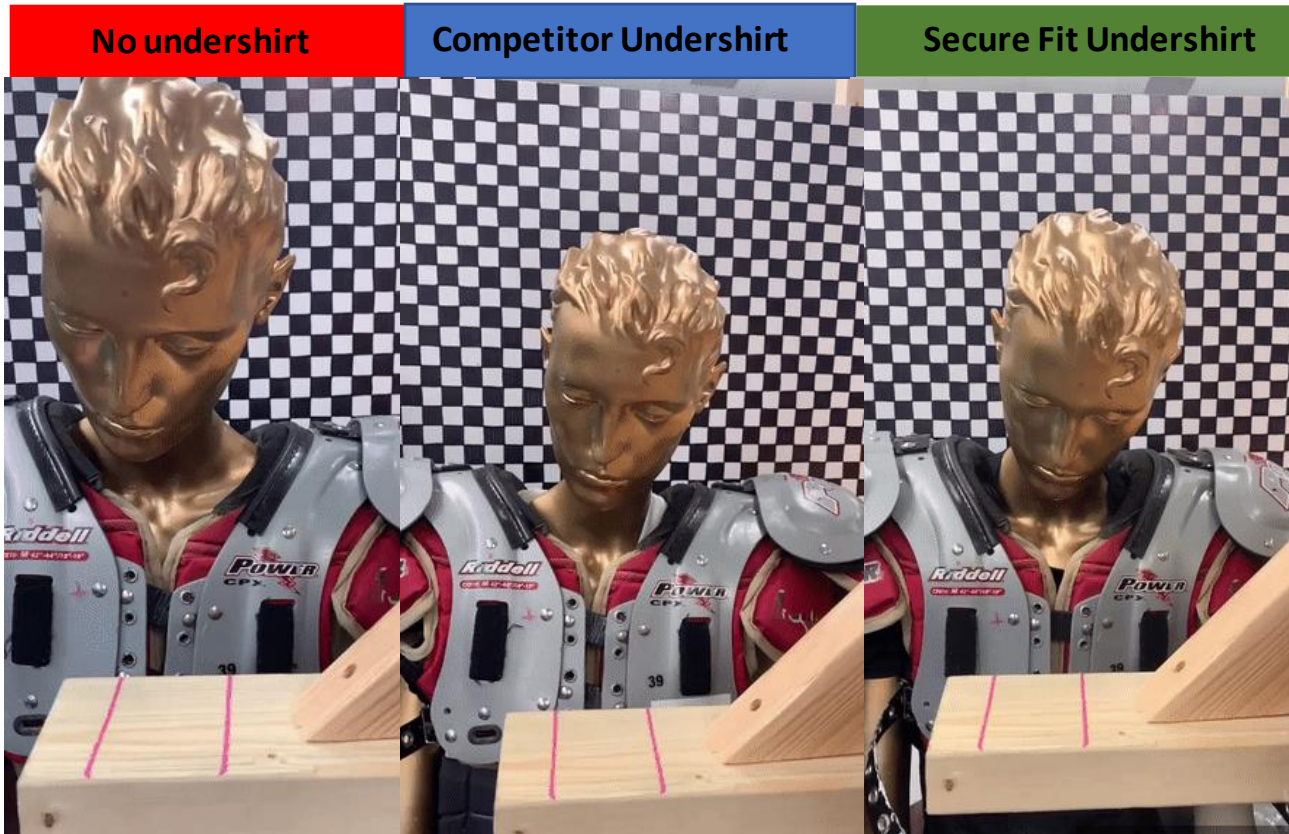
Slip Test

Measurement: Displacement (m)



Sawyer O'Bryan

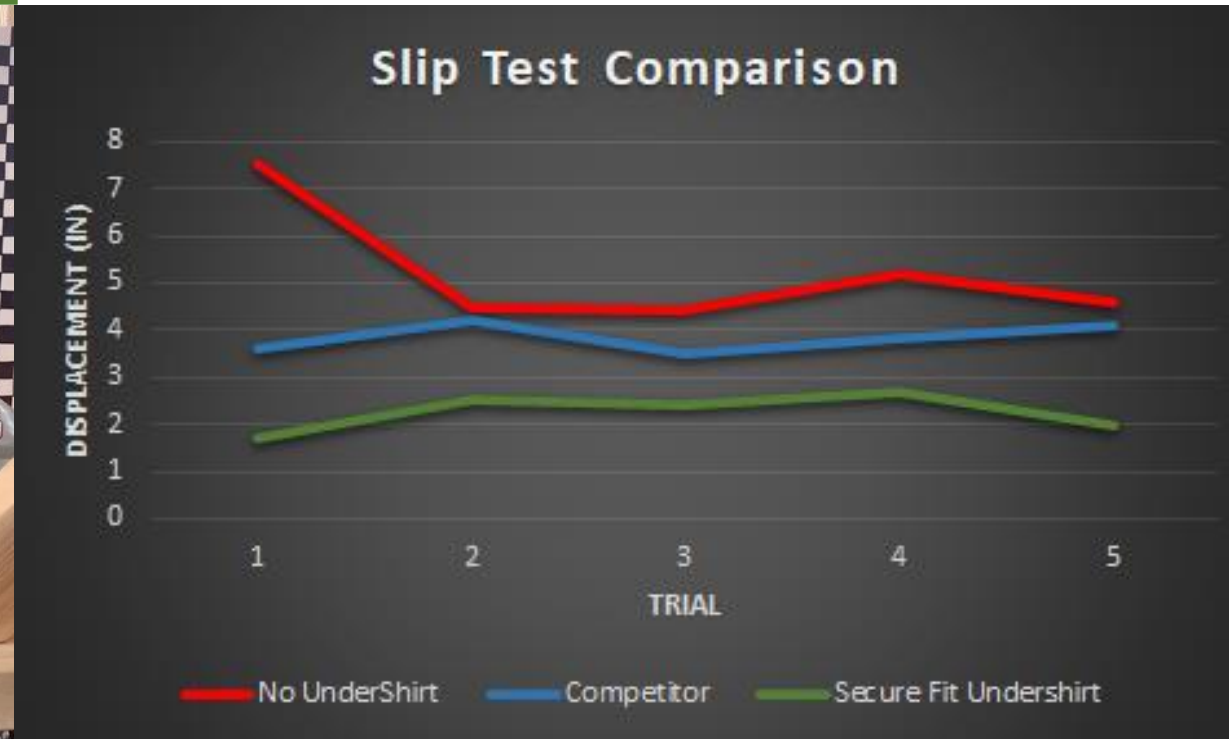
Slip Test-Comparison



Average: 5.24 in

Average: 3.84 in
Reduction: 26.7%

Average: 2.86 in
Reduction: 45.4%



Sawyer O'Bryan

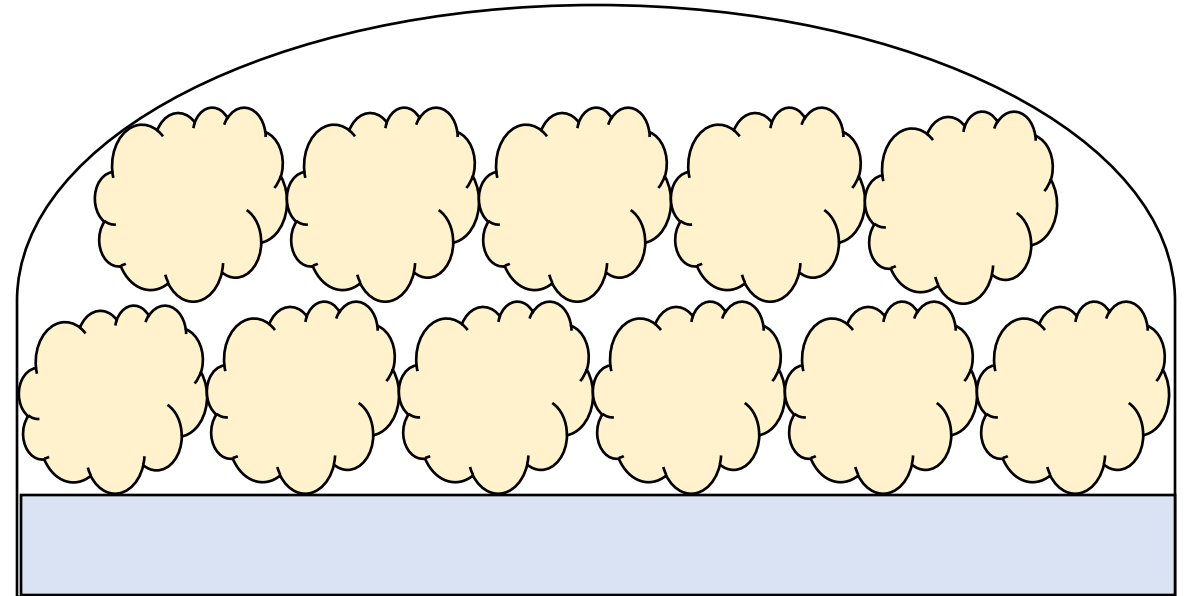
Pendulum Impact Test



Sawyer O'Bryan

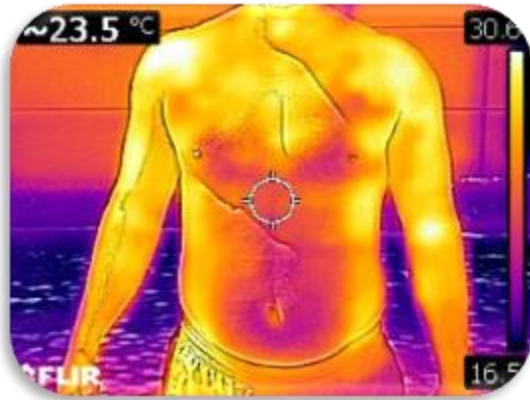
Pendulum Impact Test Results

| Mean Percent Force Reduction | |
|------------------------------|-----------|
| Composite Foam Pad | 52.2891 % |
| Gel Shredded Memory Foam Pad | 21.9785 % |
| Nike Competition Padding | 27.6143 % |



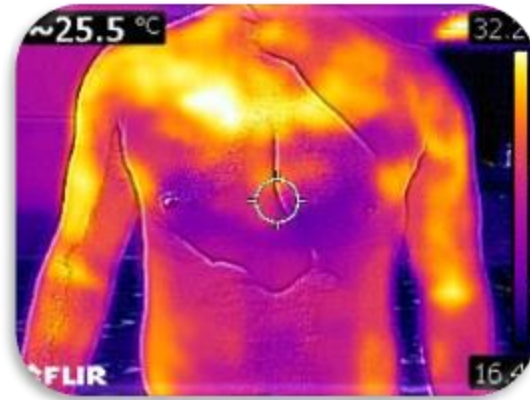
Sawyer O'Bryan

Thermal Testing – 2 Laps



Before Running

77.90°F



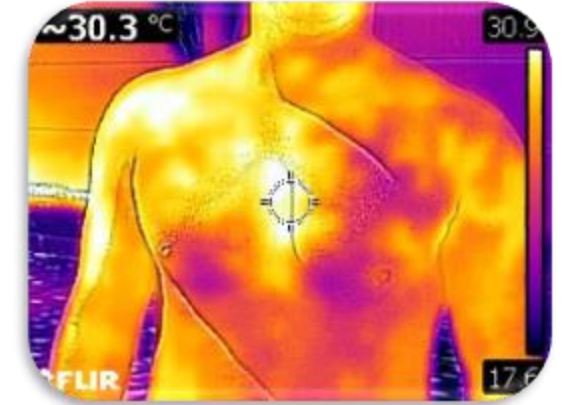
No undershirt

82.76°F



Competition Undershirt

86.90°F



Secure Fit Football Undershirt

89.24°F



Temperatures differ by 2-3°C across body

Sawyer O'Bryan

Competition



Nike Pro HyperStrong Sleeveless Undershirt
Price: \$65



Secure Football Undershirt
Final Prototype Manufacturing Cost: \$44
Estimated Bulk Production Per Shirt: \$22

Sawyer O'Bryan

Future Work

 Undershirt impact testing with shoulder pads

 Field implementation with volunteers

 Analysis on damping properties of undershirt

 Durability testing of materials

 Professional designers

Vivi Huynh

Lessons Learned

- ✓ Do not assume
- ✓ Self-regulate procedures when there is lack of prior knowledge or foundation
- ✓ Recreating a repeatable, controlled impact is challenging
- ✓ Impact sensors are more complex than indicated
- ✓ Reducing injury can only be inferred when the project does not include injury
- ✓ Comfort is subjective
- ✓ Account for potential roadblocks in design process

Vivi Huynh

Summary



The padding on the shoulder and neck is made of shredded gel memory foam, polyurethane foam, all wrapped in ultra-weather resistant nylon fabric sheet.



Composite foam padding reduced impact by **52.29%** however, further testing with more advanced instruments is necessary



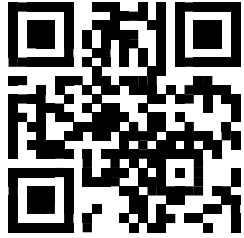
Secure fit football undershirt protects the neck from impact and decreases the motion of shoulder pads.

Morgan Sefcik

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5. Schutt Air XP Pro Q10 Football Helmet. (n.d.). Retrieved November 06, 2020, from <https://www.schuttsports.com/air-xp-pro-q10-football-helmet.html>
6. Vinoski, J. (2019, May 29). Guarding Against Concussions: Startup Auxadyne Makes Ultra-Cushioning Foam For Helmets, Prosthetics. Retrieved November 06, 2020, from <https://www.forbes.com/sites/jimvinoski/2019/05/24/auxadynes-foam-padding-might-just-save-your-head-and-other-parts-too/?sh=2f8c15853969>
7. Broekaart, D. Foam Indentation with Abaqus FEA. Retrieved November 06, 2020, from <https://info.simuleon.com/blog/foam-indentation-with-abaqus-fea>

Contact Information

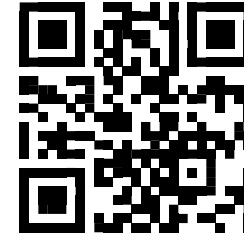


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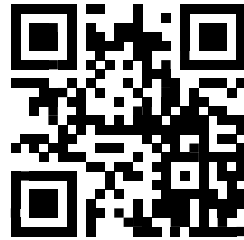


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Slides Link

Surveys



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Functions



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Targets & Metrics



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Compression Test



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Pendulum Test



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Fit Optimization



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Undershirt Design



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Shoulder Pad Progression



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Slip Test



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Pendulum Impact Test



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Thermal Testing



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Shake Test



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Future Work



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Air Pocket Progression



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Lessons Learned



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Summary



48

Mass Production Cost

| Item | # of shirts that can be made | Cost | Cost per unit |
|----------------------|------------------------------|-------|---------------|
| Shirt | 1 | 3 | 3.00 |
| Shredded Memory Foam | 1000 | 300 | 0.3 |
| Polyurethane Foam | 21 | 16.94 | 0.806666667 |
| Nylon | 18 | 105 | 5.833333333 |
| Zipper | 1 | 0.43 | 0.43 |
| Polyester | 7 | 14 | 2 |
| Super glue | 3 | 28.49 | 9.496666667 |
| Total Cost Per Unit | | | 21.87 |

| Consistency Check | | |
|-----------------------|-------|------|
| {Ws} | {W} | Cons |
| 3.78 | 0.502 | 7.54 |
| 1.19 | 0.168 | 7.09 |
| 0.67 | 0.104 | 6.45 |
| 0.91 | 0.143 | 6.40 |
| 0.25 | 0.041 | 6.18 |
| 0.27 | 0.043 | 6.35 |
| Average (λ) | | 6.67 |

| Consistency Comparison | |
|------------------------|-------|
| $\lambda - n$ | 0.67 |
| $n - 1$ | 5 |
| Consistency index | 0.133 |
| RI Value | 1.35 |
| Consistency Ratio | 0.099 |