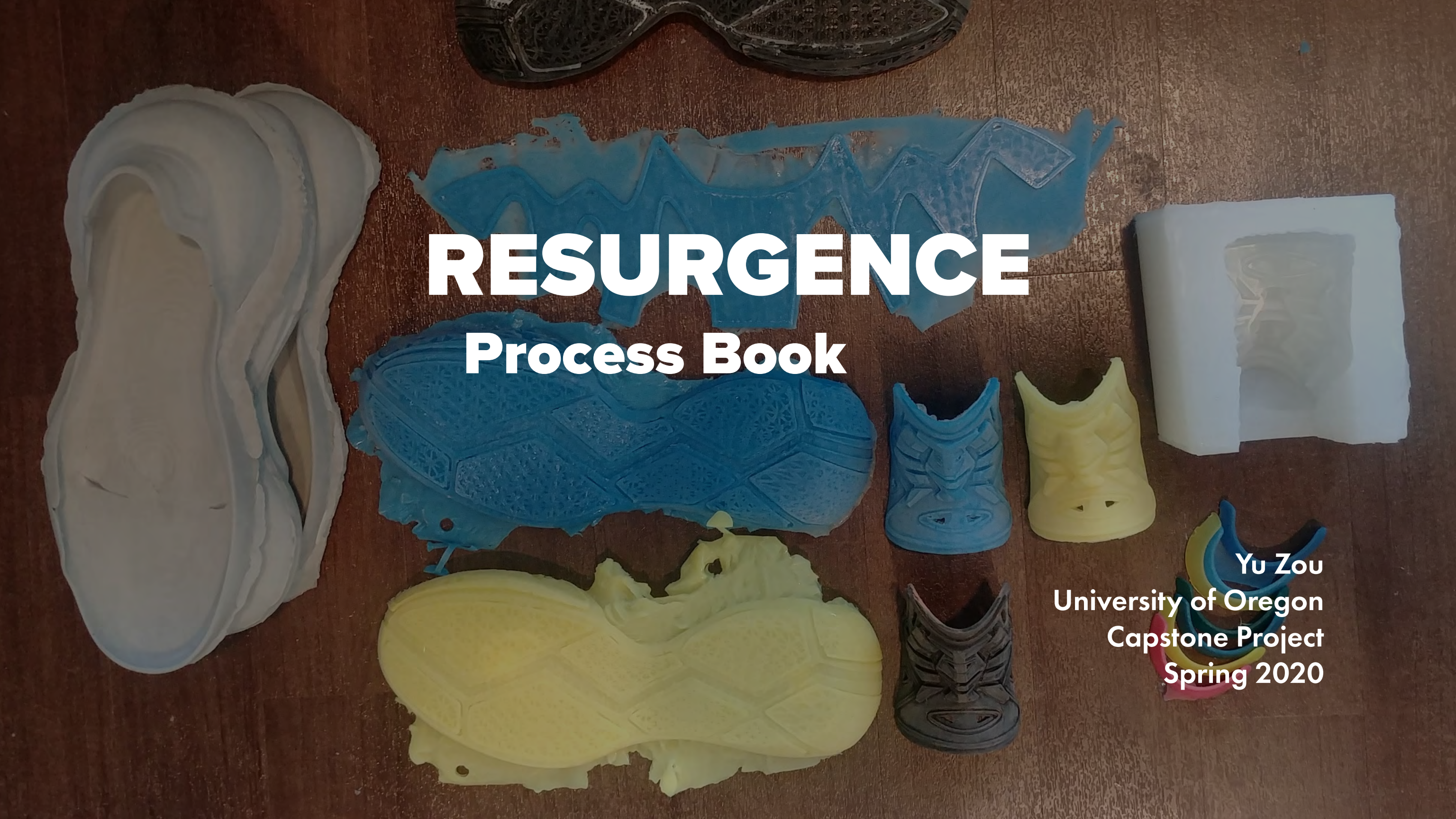


RESURGENCE

Contents:

- Process Book
- Spring Presentation
- Winter Presentation
- Final Paper

Yu Zou
University of Oregon
Capstone Project
Spring 2020

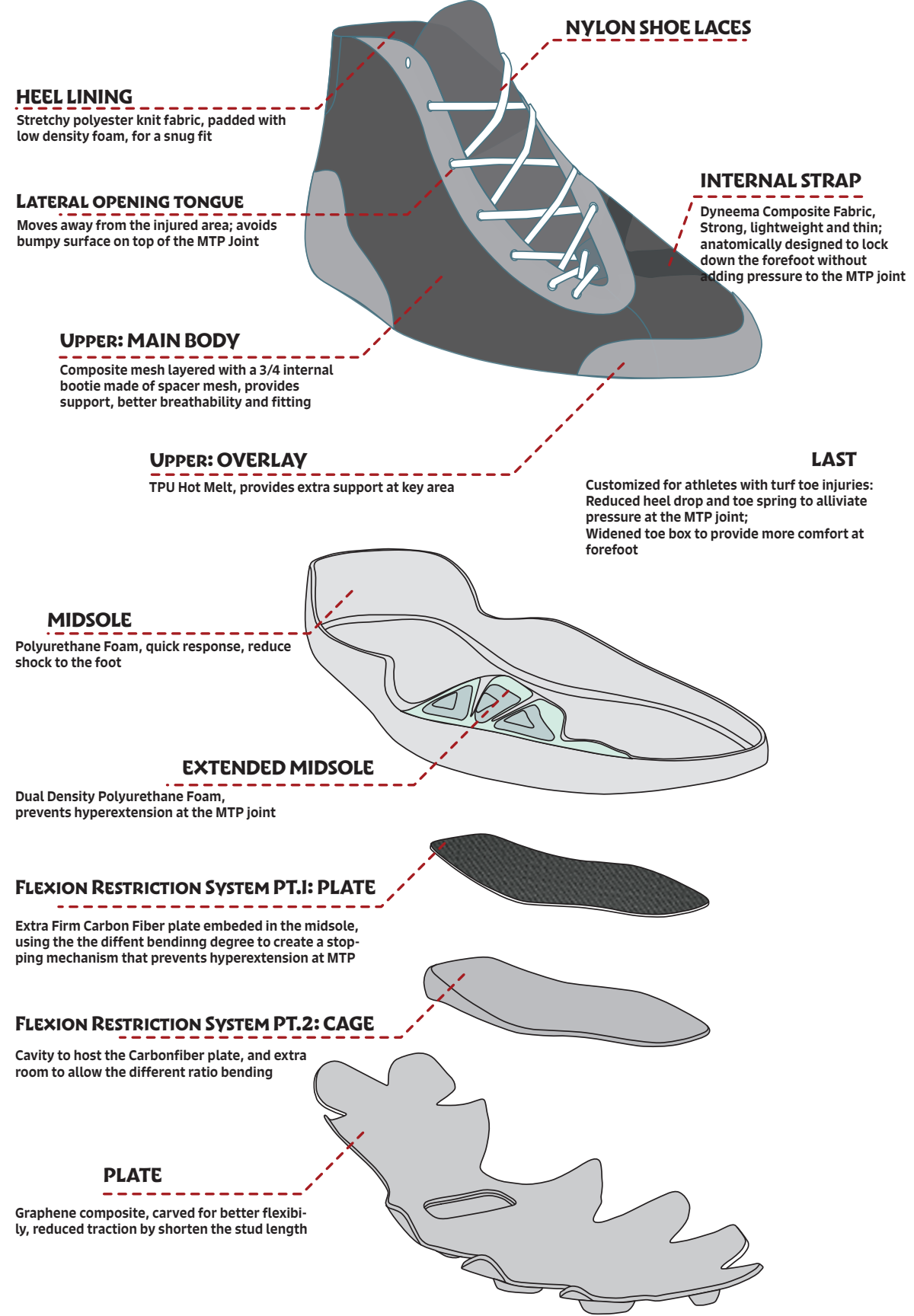
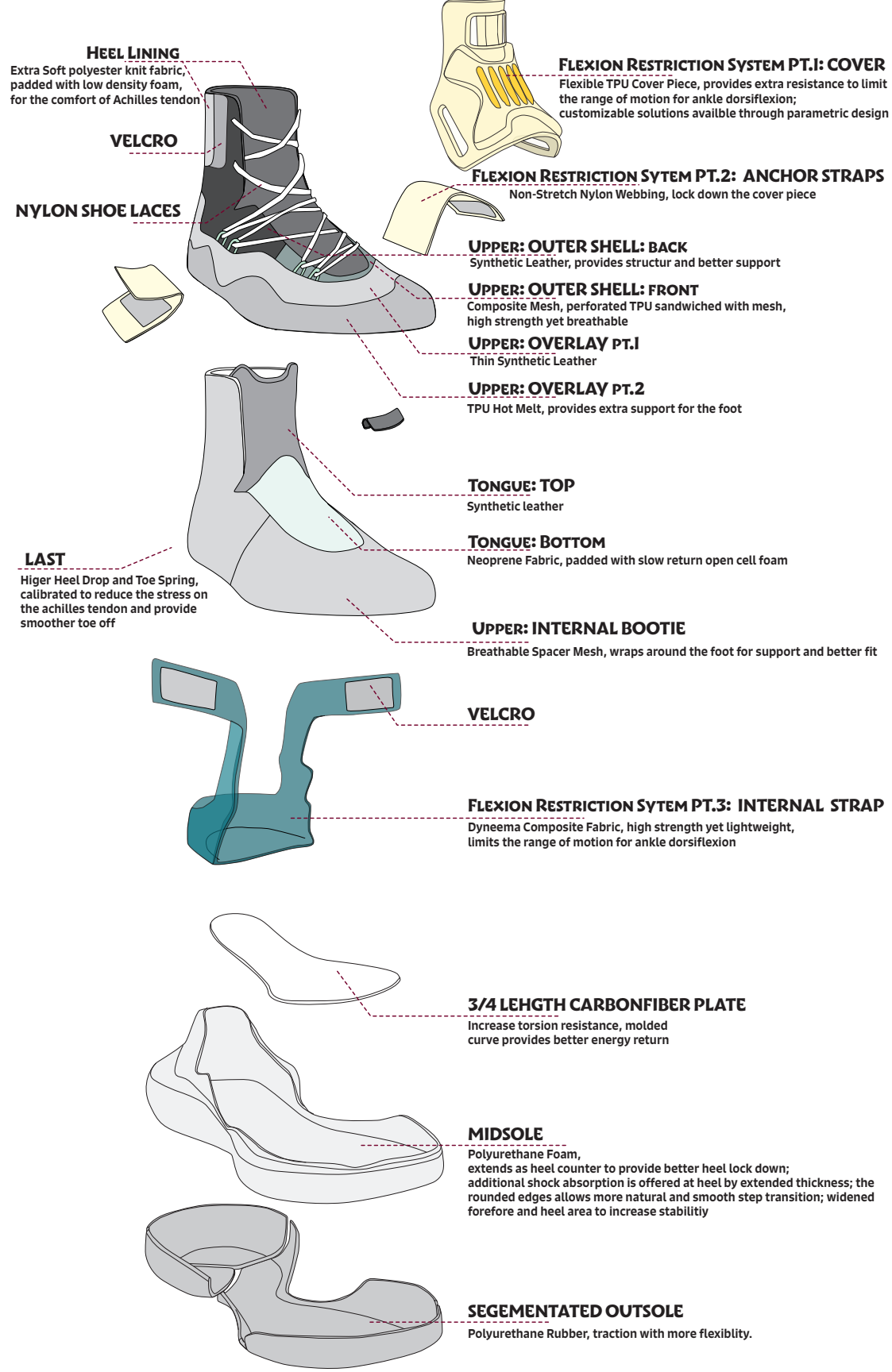


RESURGENCE

Process Book

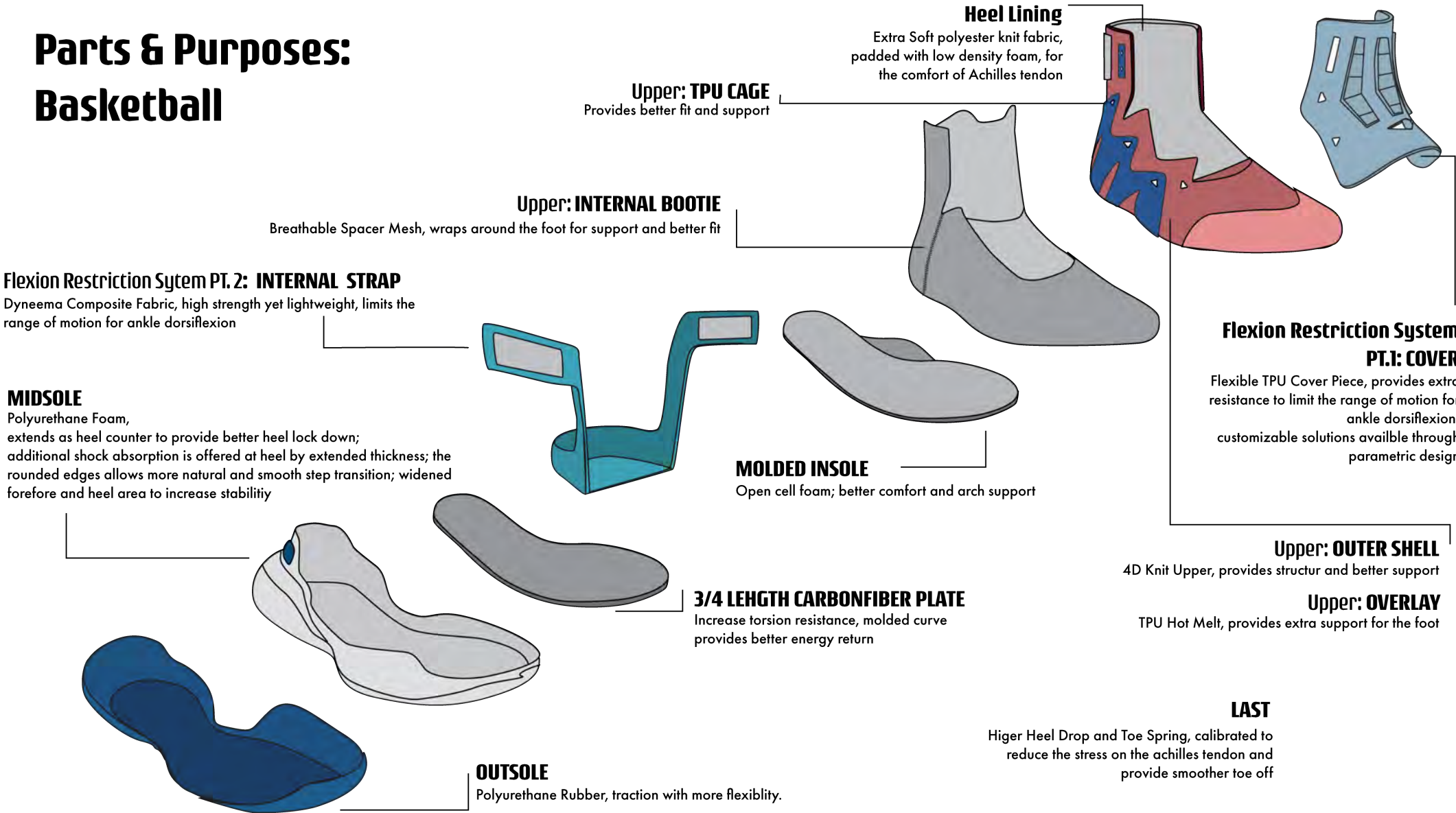
Yu Zou
University of Oregon
Capstone Project
Spring 2020

EXPLODED VIEW(V.1.0)



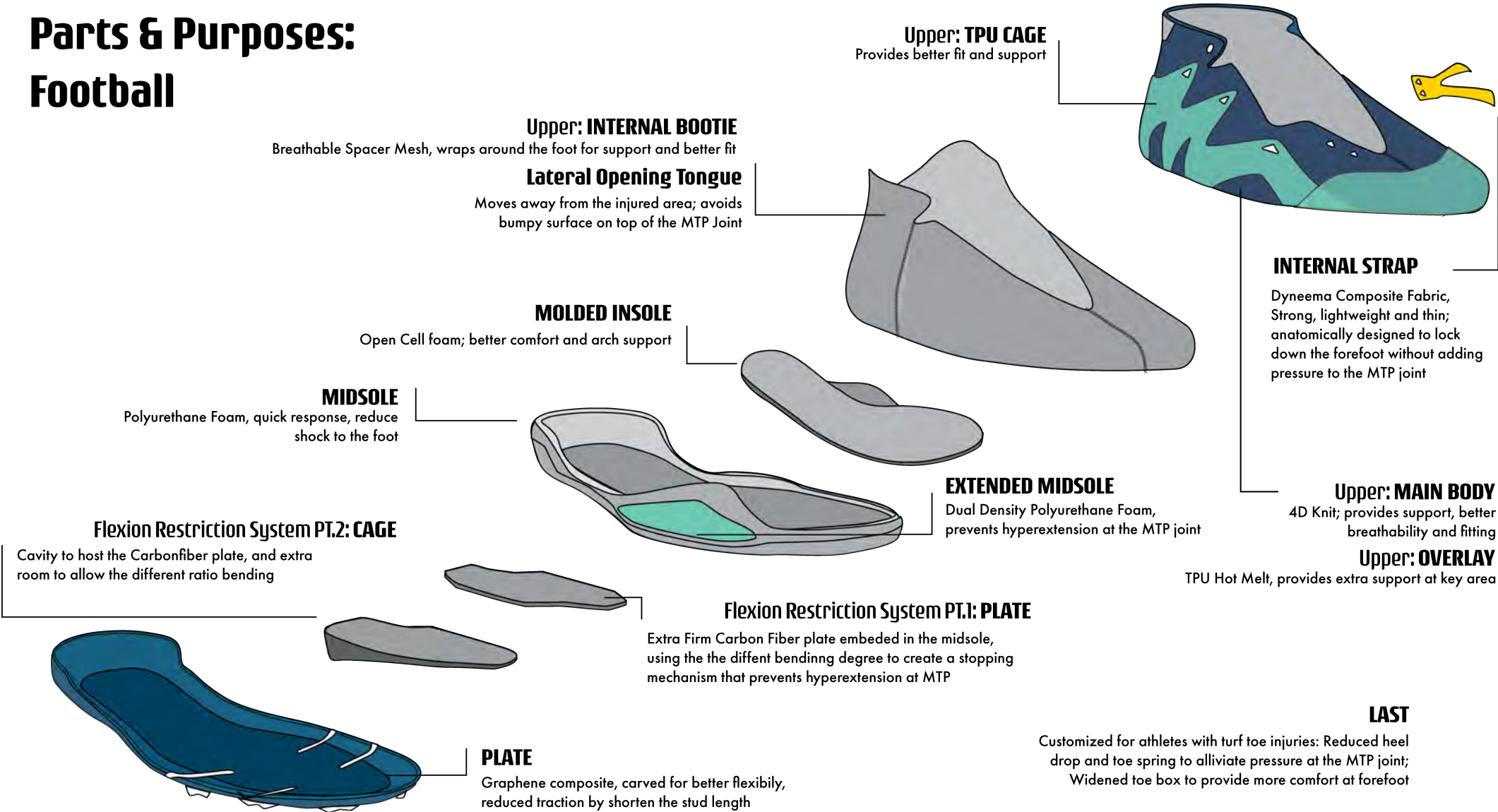
EXPLODED VIEW(v.2.0)

Parts & Purposes: Basketball



EXPLODED VIEW(v.2.0)

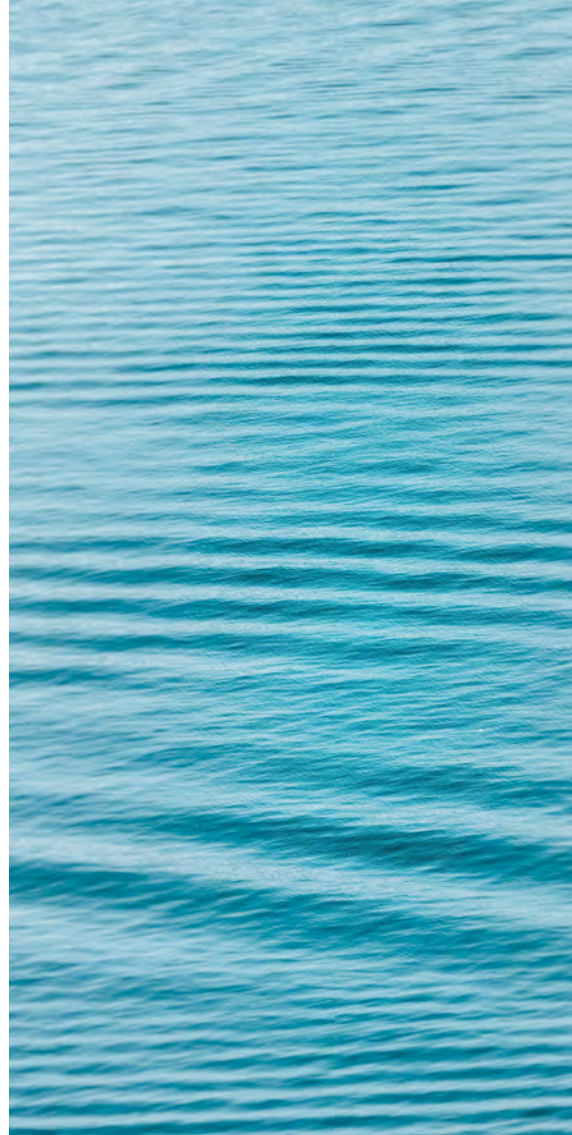
Parts & Purposes: Football





MOOD
Basketball

RESILIENCE · STABILITY · COMFORT



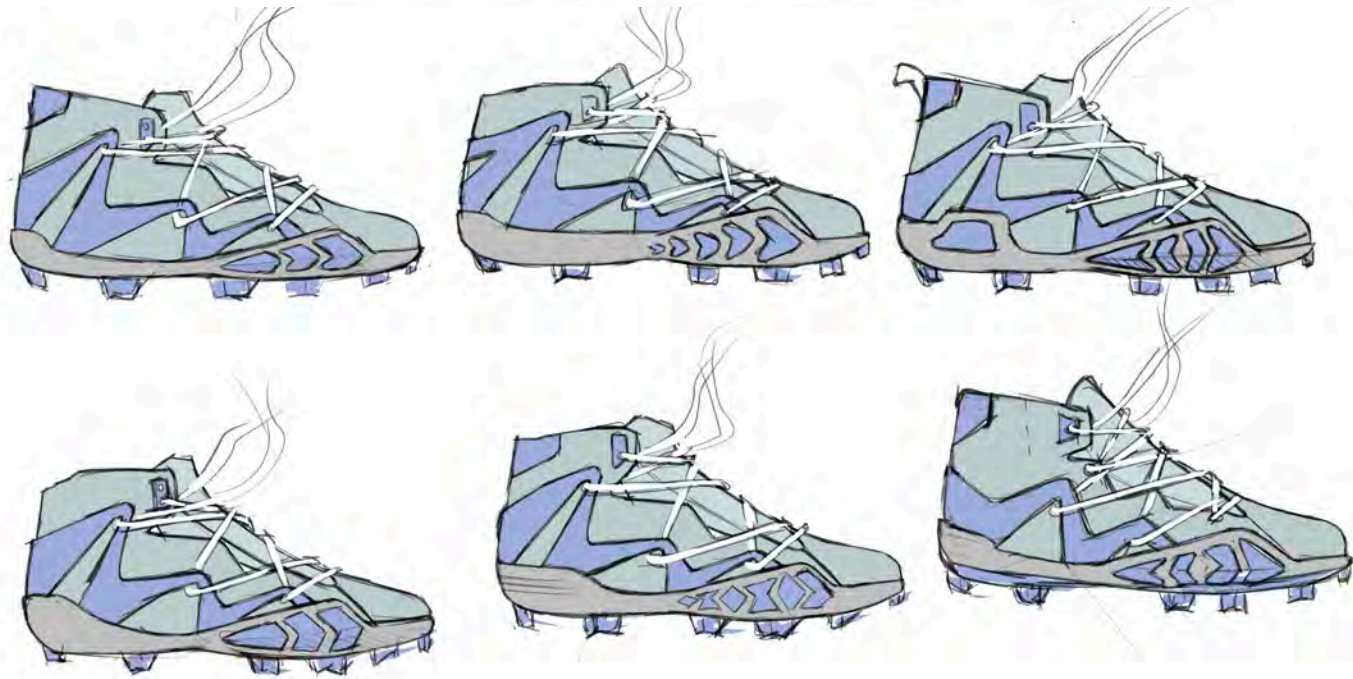
MOOD
Football

RESILIENCE · SUPPORT · COMFORT

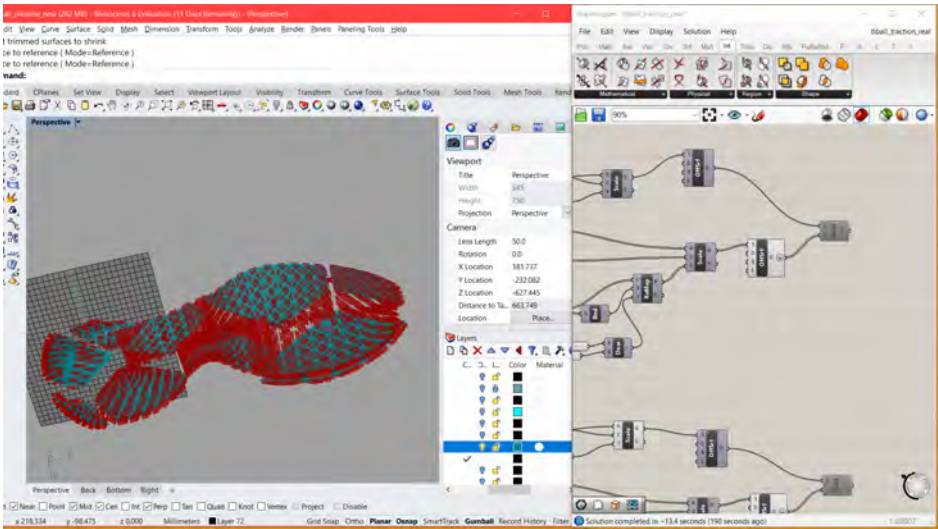
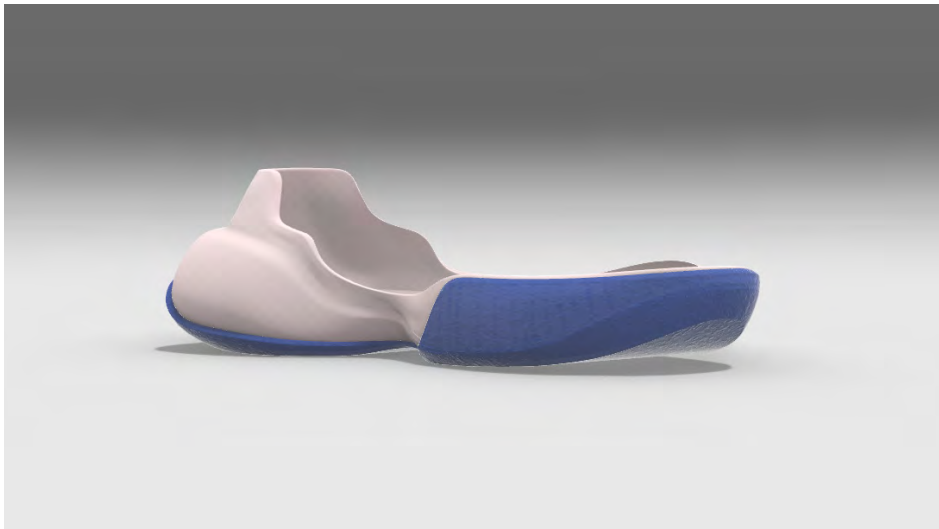
SKETCHES



SKETCHES

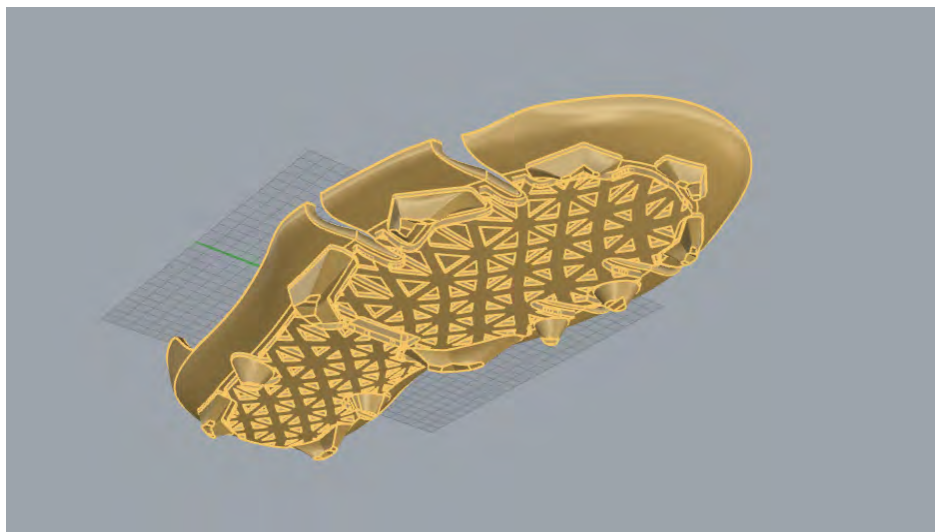
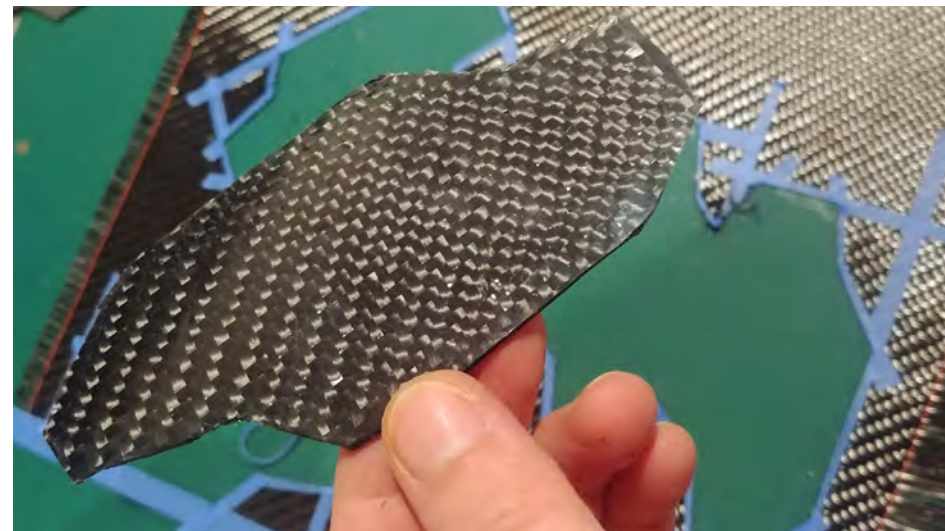


PROTOTYPING





PROTOTYPING







RESURGENCE

Post Achilles Injury Recovery Training Footwear
for elite/subelite basketball players

LAST Specifically tuned to help alleviate pressure at
Achilles Tendon and facilitates smoother movements



Raised heel drop:

Reduces pressure at Achilles tendon,
also provides better propulsion

Raised toe spring:

Allows smoother toe off

PARTS & PURPOSES





RESURGENCE

Post MTP joint Injury Recovery Training Cleats

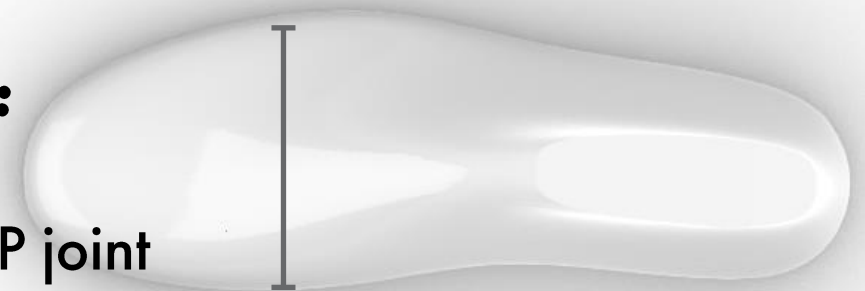
for elite/subelite football players

LAST

Specificly tuned to help alleviate pressure at injured area

Widened forefoot width:

Anatomical design avoids unnecessary stress at the MTP joint



Reduced heel drop and toe spring:

Allowing the foot to stay at natural position; Reduces pressure at the forefoot by distributing the force more evenly along the foot



PARTS & PURPOSES















COLORWAYS



Team Inspired Colorways
or DIY options











ONLINE CUSTOMIZATION OPTION

At the product page, customers can pick the part of shoe to change the color and graphic design, the 3D preview will update at real time



BASE



TONGUE



TOE OVERLAY



STABILITY CAGE



FRS TONGUE COVER



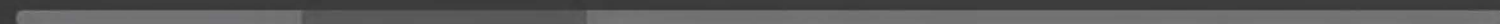
FRS ANKLE STRAP



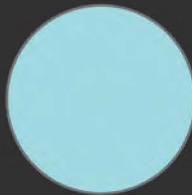
MIDSOLE



OUTSOLE



OUTSOLE



DONE

cancel

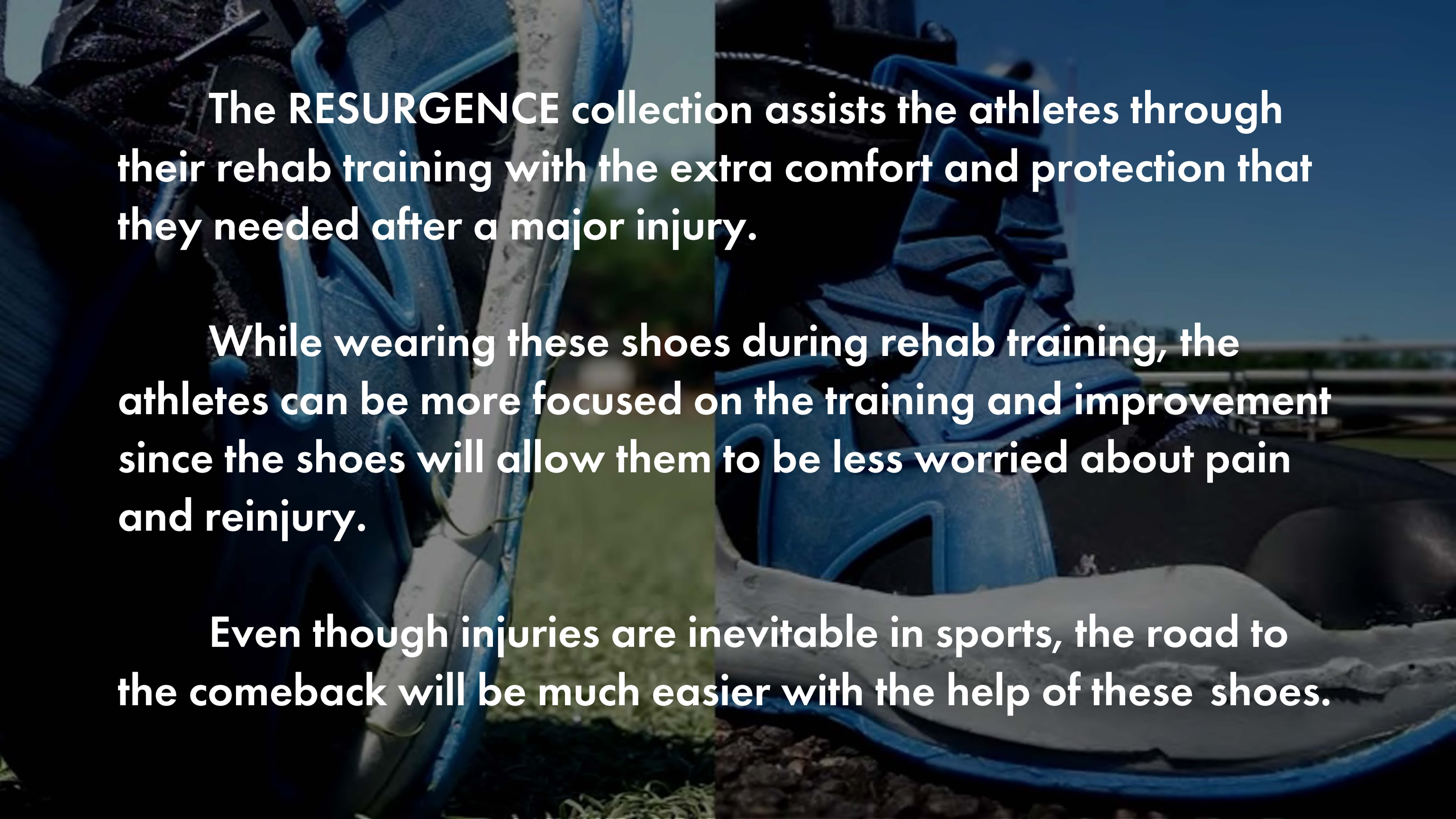
PACKAGING

The Box: Made with Recycled Plastic. Can be re-used as general container. The shape design allows easy and steady stacking.



The Drawstring Bag: Made with Recycled Polyester Woven Fabric. Use to carry the shoes on their own, or to separate the shoes from clean clothes in the gym bag.



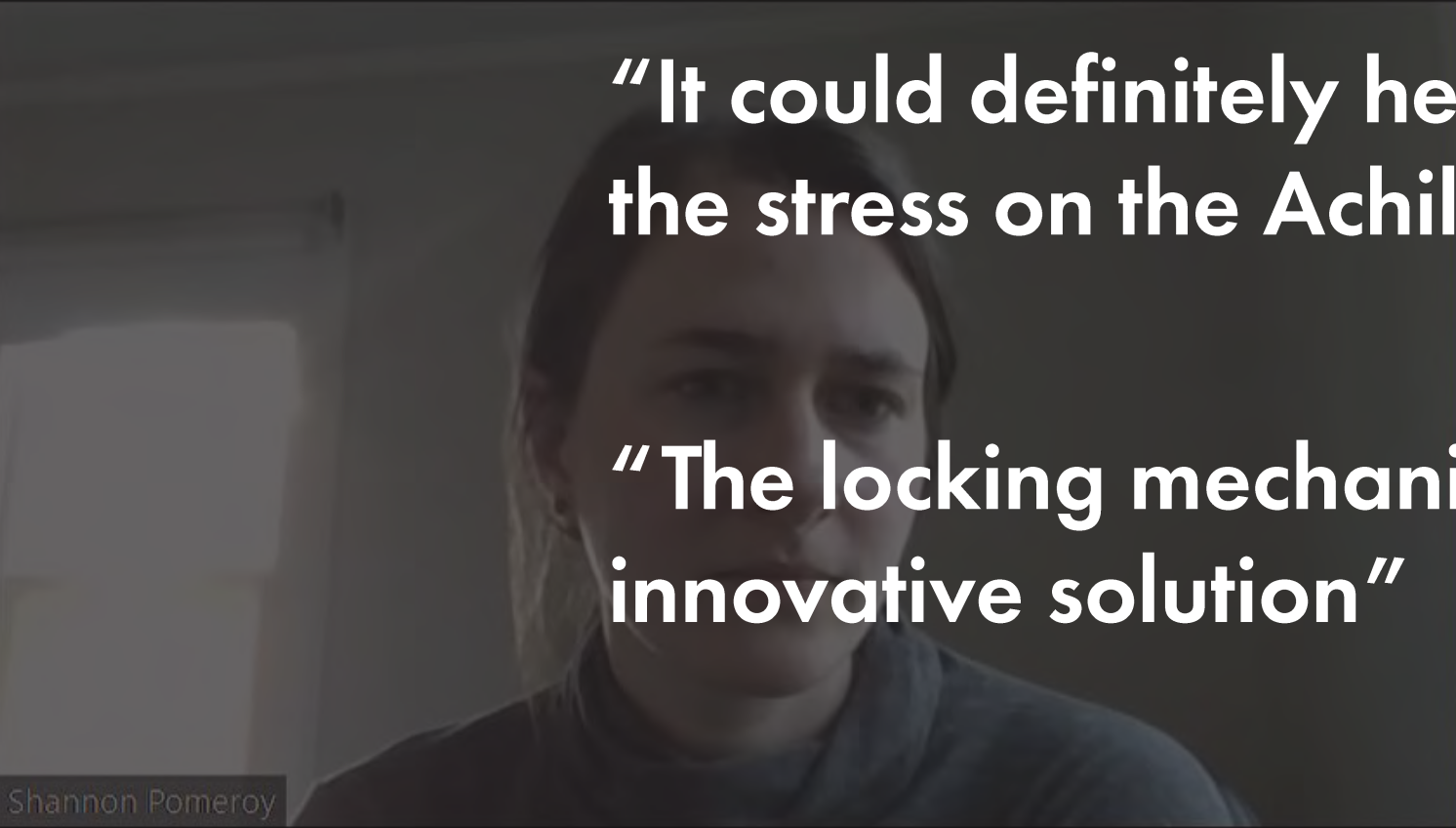


The RESURGENCE collection assists the athletes through their rehab training with the extra comfort and protection that they needed after a major injury.

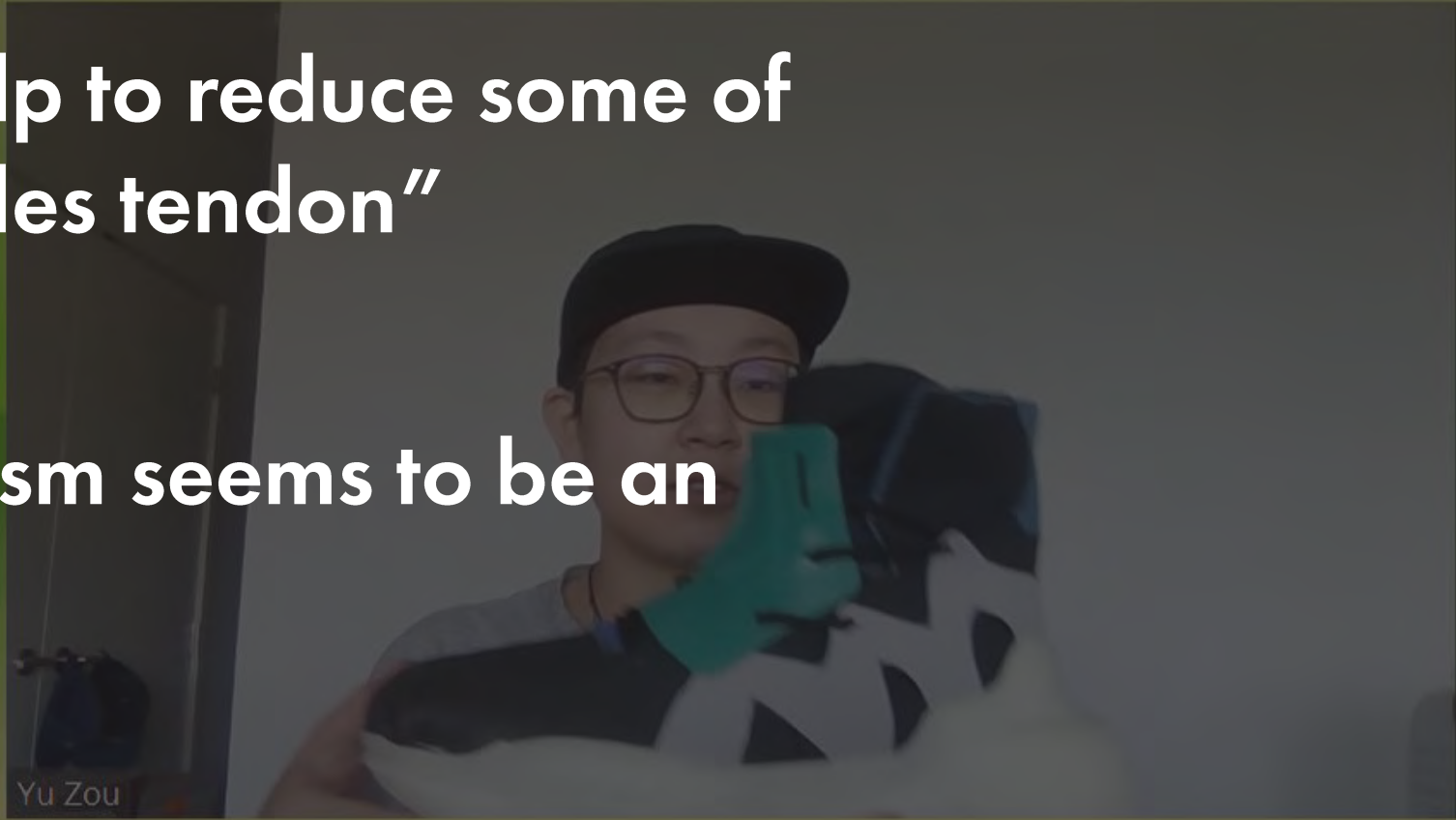
While wearing these shoes during rehab training, the athletes can be more focused on the training and improvement since the shoes will allow them to be less worried about pain and reinjury.

Even though injuries are inevitable in sports, the road to the comeback will be much easier with the help of these shoes.

EXPERTS INSIGHTS

A video frame showing Shannon Pomeroy, a woman with dark hair, speaking. The text is overlaid on the right side of the frame.

“It could definitely help to reduce some of the stress on the Achilles tendon”

A video frame showing Yu Zou, a man wearing a black cap and glasses, holding a green object. The text is overlaid on the left side of the frame.

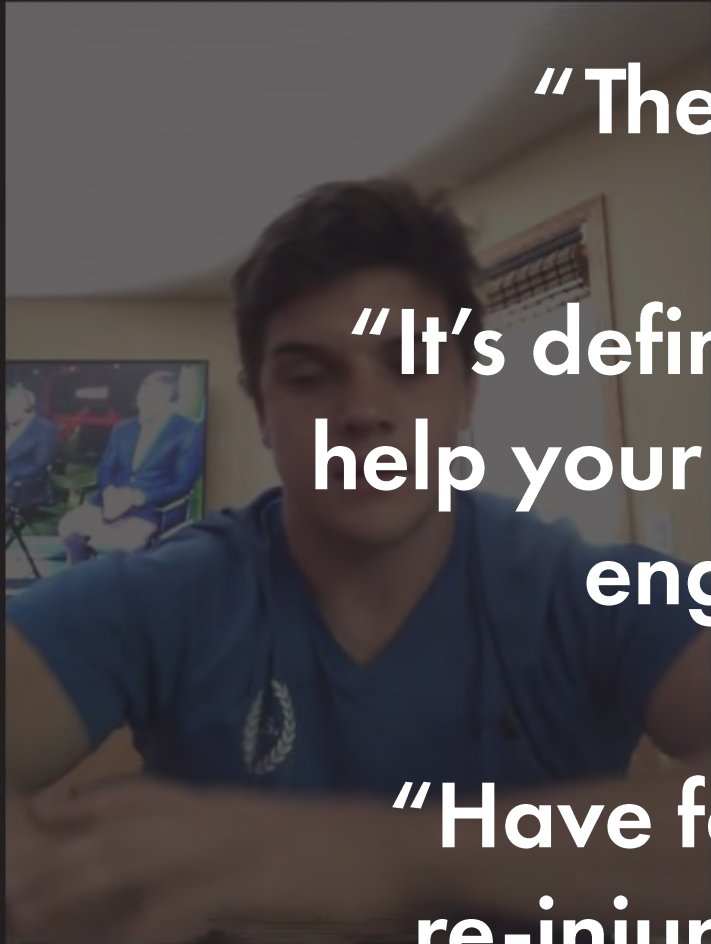
“The locking mechanism seems to be an innovative solution”

Shannon Pomeroy

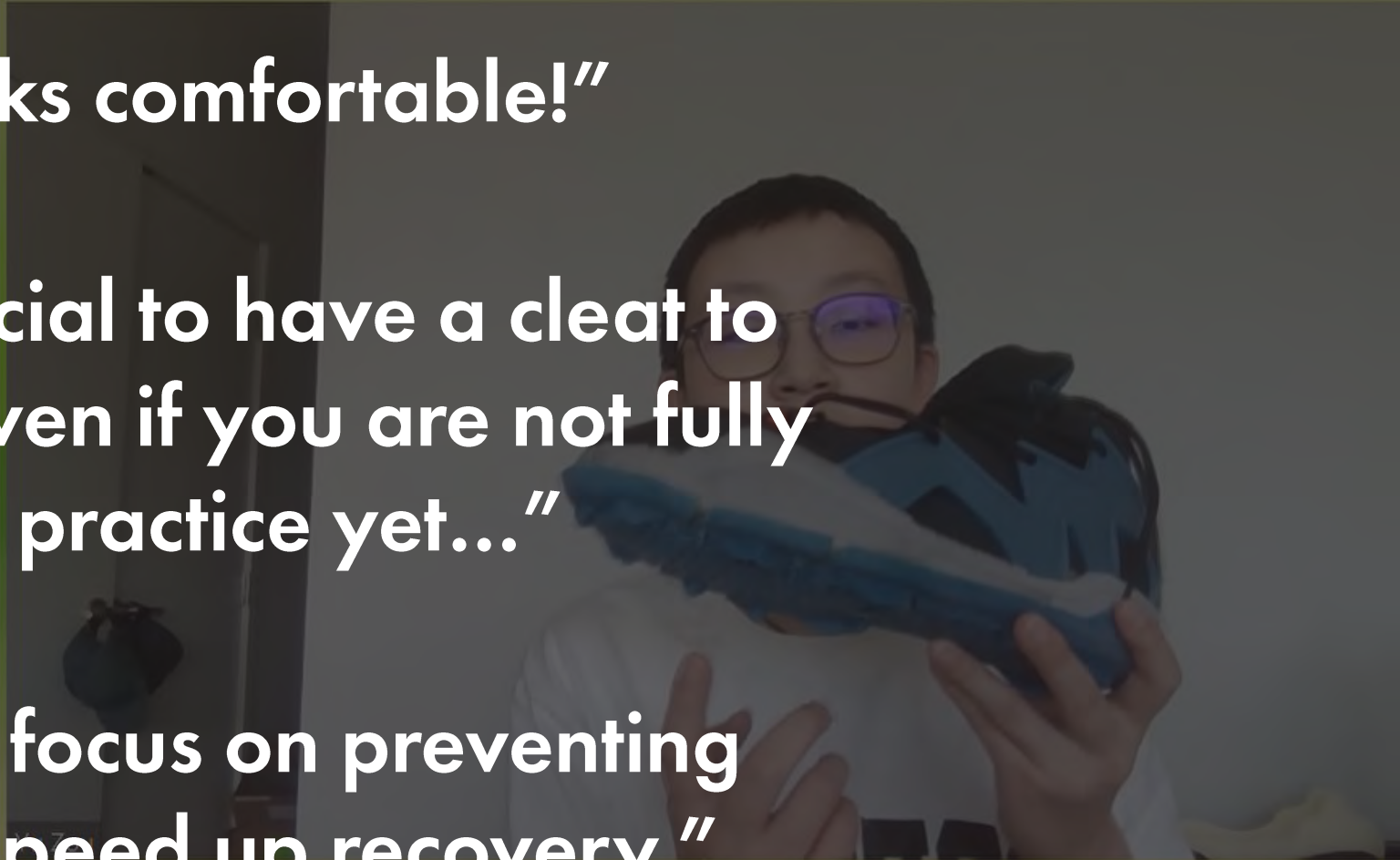
Yu Zou

-- **Shannon Pomeroy,**
*Nike Explore Team (ETW/FLEX),
Applied Product Connection*

VALIDATION BY ATHLETE



“The bottom looks comfortable!”



“It’s definitely beneficial to have a cleat to help your recovery, even if you are not fully engaged in the practice yet...”

“Have features that focus on preventing re-injury can help speed up recovery.”

-- **James Klecker**, *LB at University of St. Thomas*

TECH PACK

Basketball

Midsole

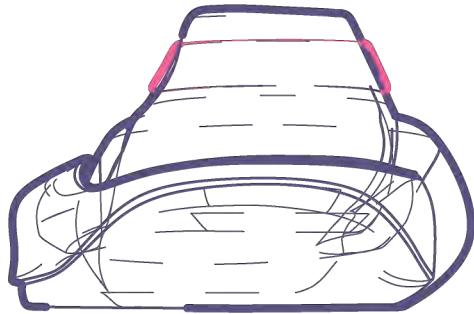
Key:



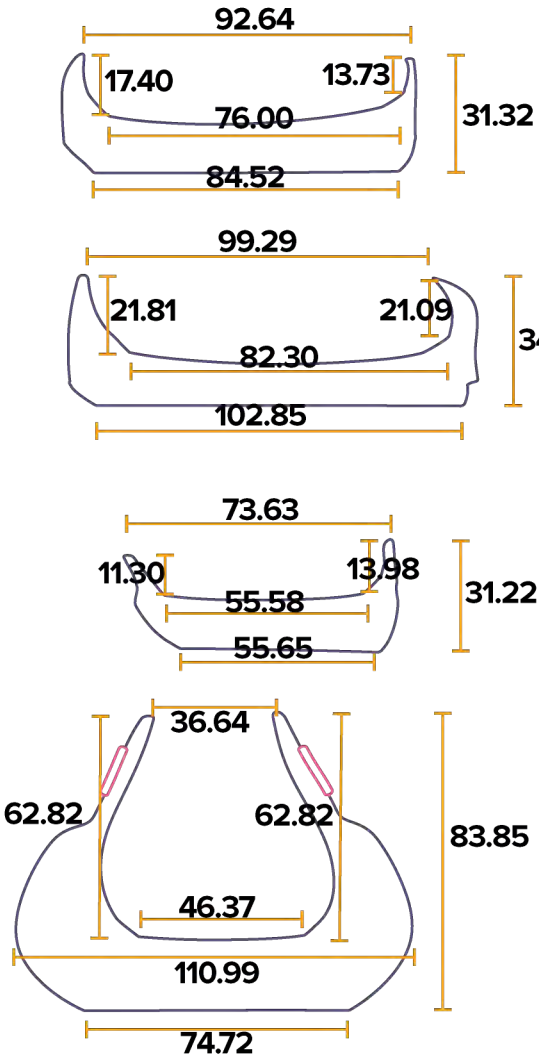
Midsole



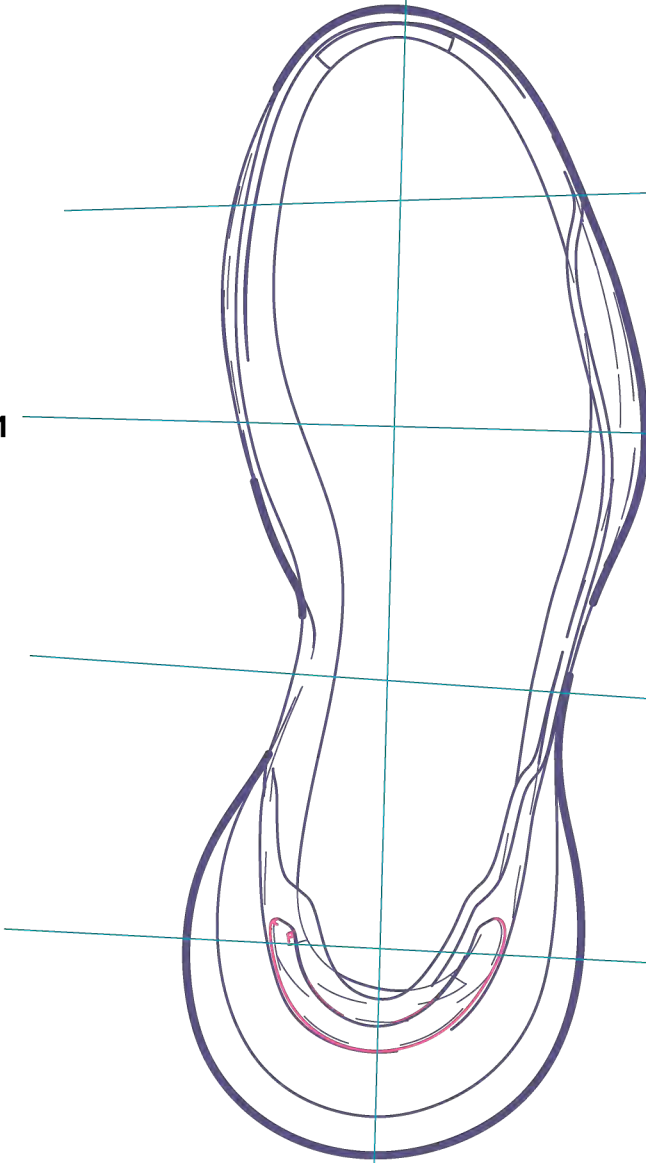
Midsole--Heel Counter



53.87



SECTION



TOP



84.00

LATERAL

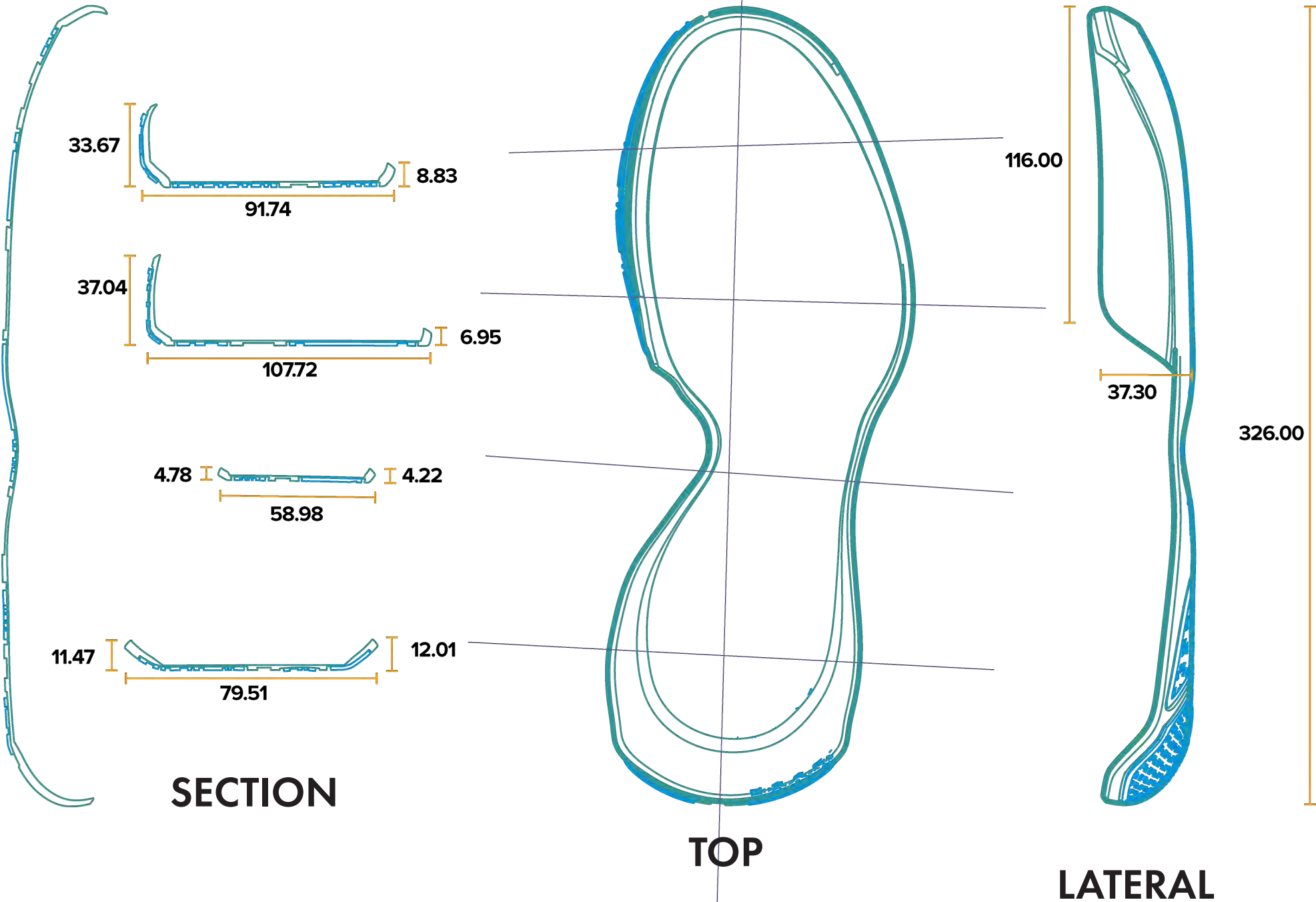
325.00

TECH PACK

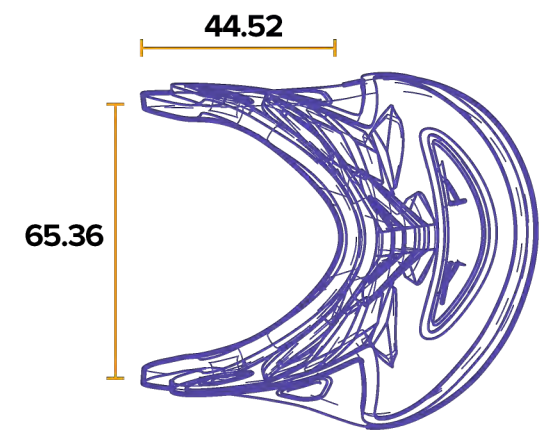
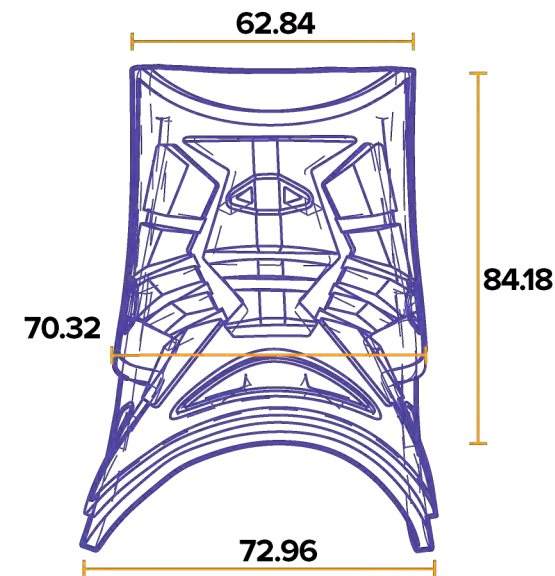
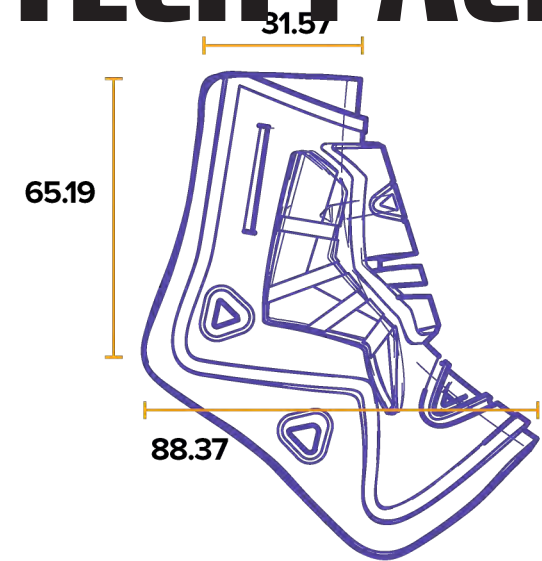
Basketball

Outsole

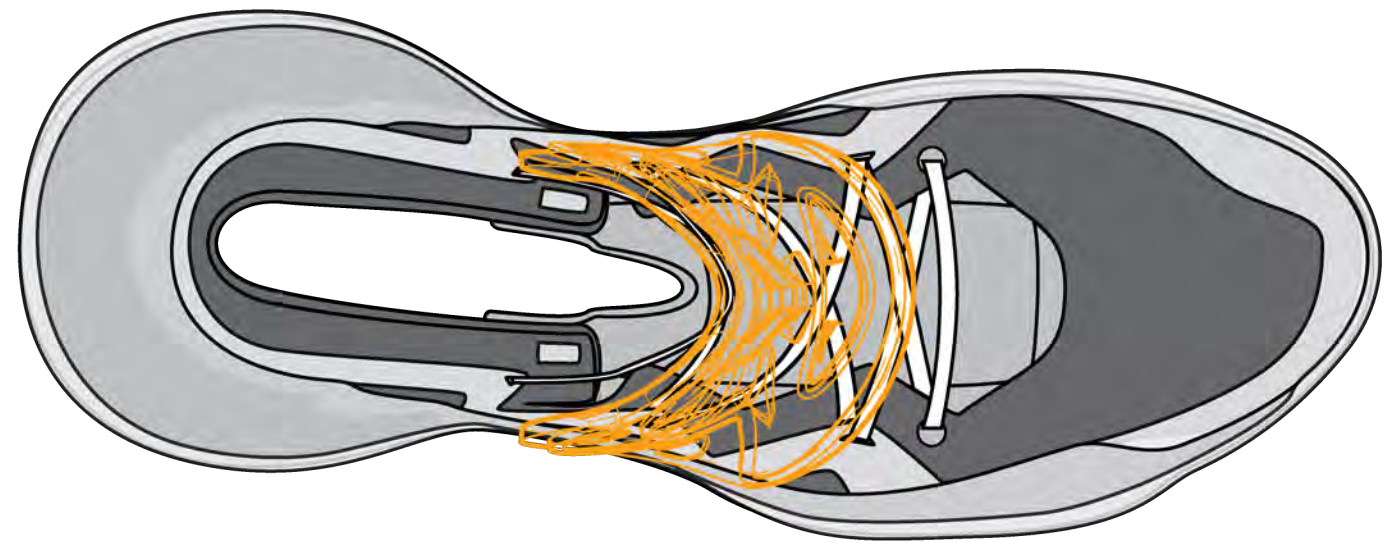
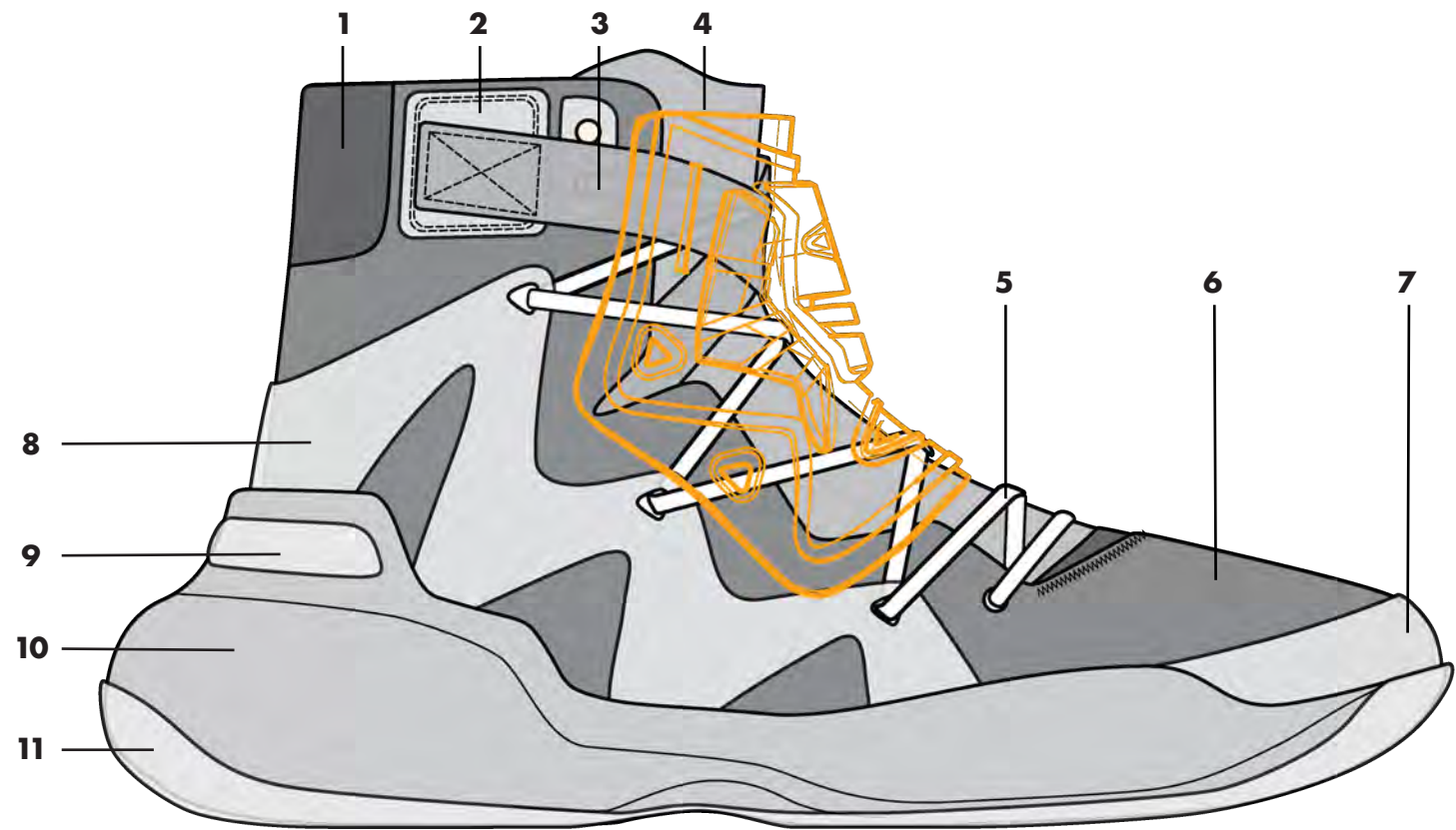
- Key:
- Outsole
 - Outsole--Traction



TECH PACK



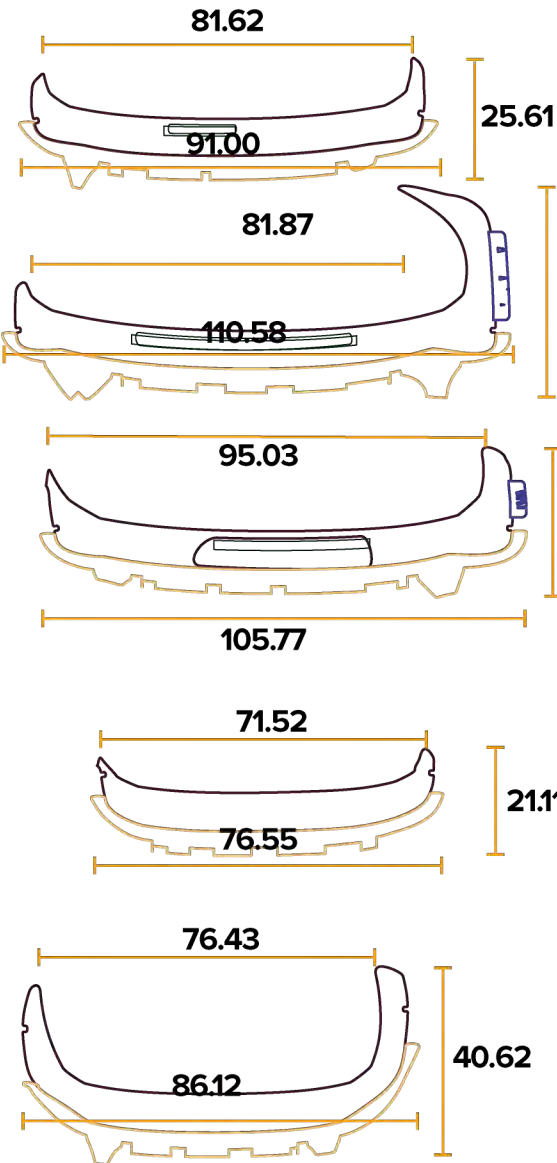
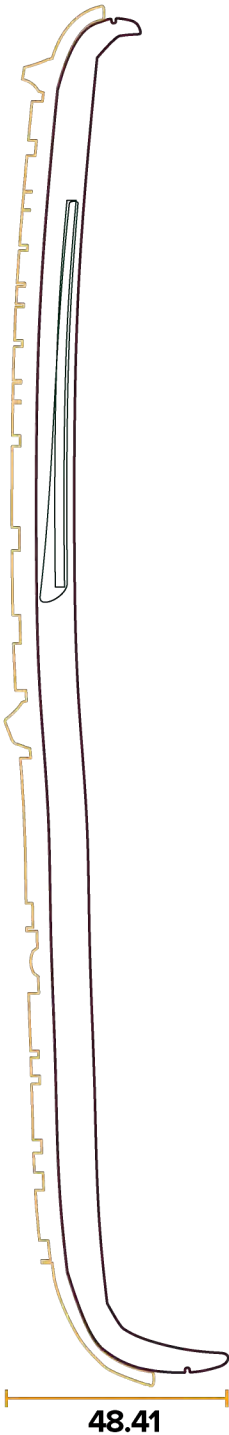
1	Polyester Knit
2	Velcro
3	1 Inch Nylon Webbing
4	Spacer Mesh
5	Nylon Lace
6	Engineered Knit
7	TPU Hot Melt
8	Graphene Enhanced TPU
9	Thermoplastic Polyurethane
10	Thermoplastic Polyurethane Foam
11	Polyurethane Rubber



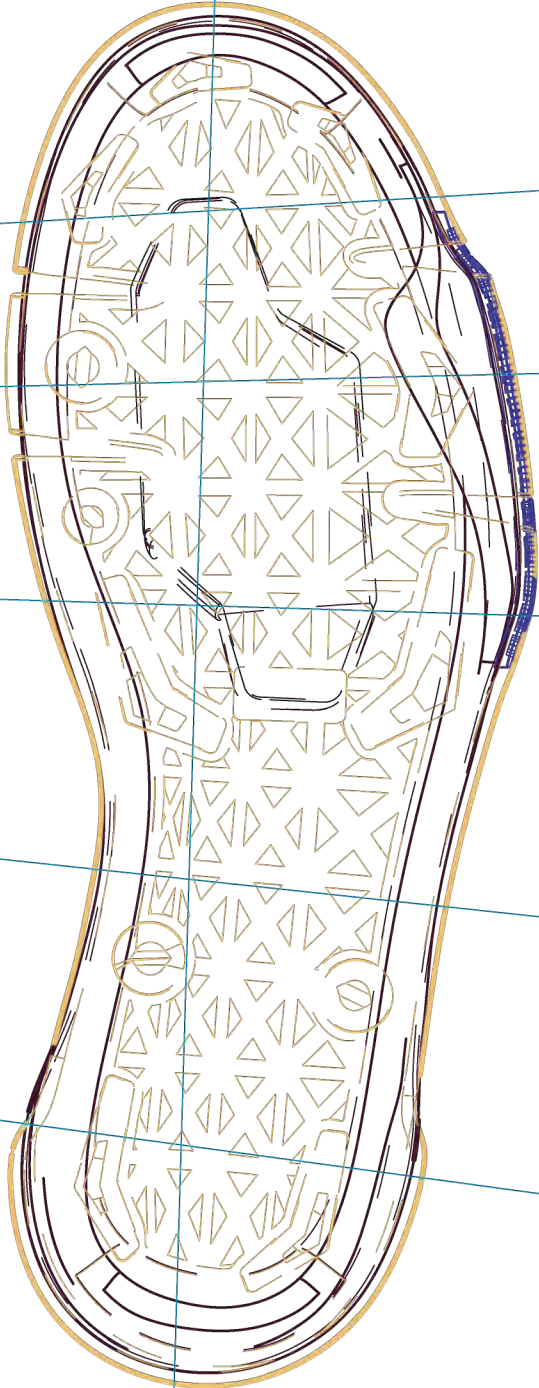
TECH PACK

Football Tooling

- Key:
- Plate
 - Midsole
 - Midsole--lateral part
 - Carbonfiber Plate



SECTION



TOP

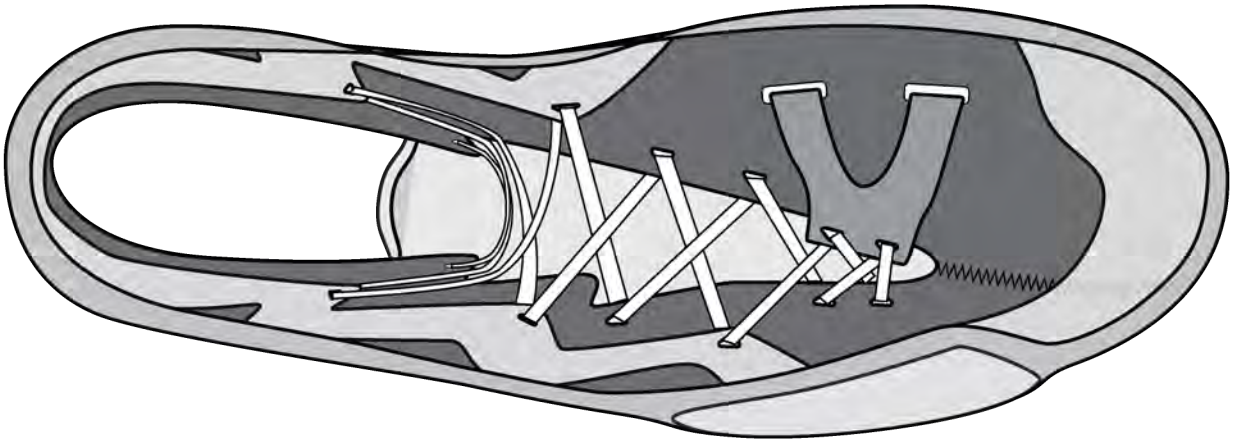


LATERAL

TECH PACK

Football

1	Polyester Knit
2	Engineered Knit
3	Spacer Mesh
4	Nylon Lace
5	Dyneema Composite TPU
6	TPU Hot Melt
7	Graphene Enhanced TPU
8	Thermoplastic Polyurethane Foam
9	Pebax Plate
10	Thermoplastic Polyurethane



RESURGENCE

Post-injury Recovery Training
Football & Basketball Footwear

Yu Zou
University of Oregon
Sports Product Design
Capstone Project



OPPORTUNITY



Acute/overuse injuries are inevitable in high performance sports.

A smooth rehab process is essential for the athlete to get back to the competition successfully.

However, there is no sports specific rehab training shoes in the market to help the athletes through the process. Athletes have to switch into regular footwear from walker boots with no transitional product.

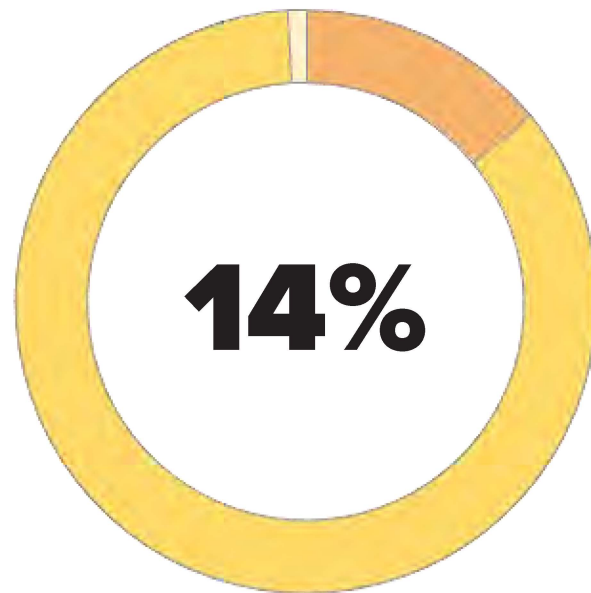
A basketball player in a blue and yellow jersey is sitting on the wooden floor of a basketball court. He is holding his right foot, which is wearing a white and pink sneaker. The background shows a crowd of spectators in a dimly lit arena.

BASKETBALL

**Training Shoes for Athletes Who endured Achilles Injuries
(Achilles Tendon Rupture/ Achilles Tendinopathy)**

WHY THIS TOPIC?

One of the most devastating injuries which affects performance for the remainder of player's career



● Unable to Return ● Return at Impaired Performance Level ● Successfully Return

According to a 2016 study: **14%** of NBA players were unable to return to function/play after Achilles tendinopathy, and that those who were able to return did so at a decreased level of performance

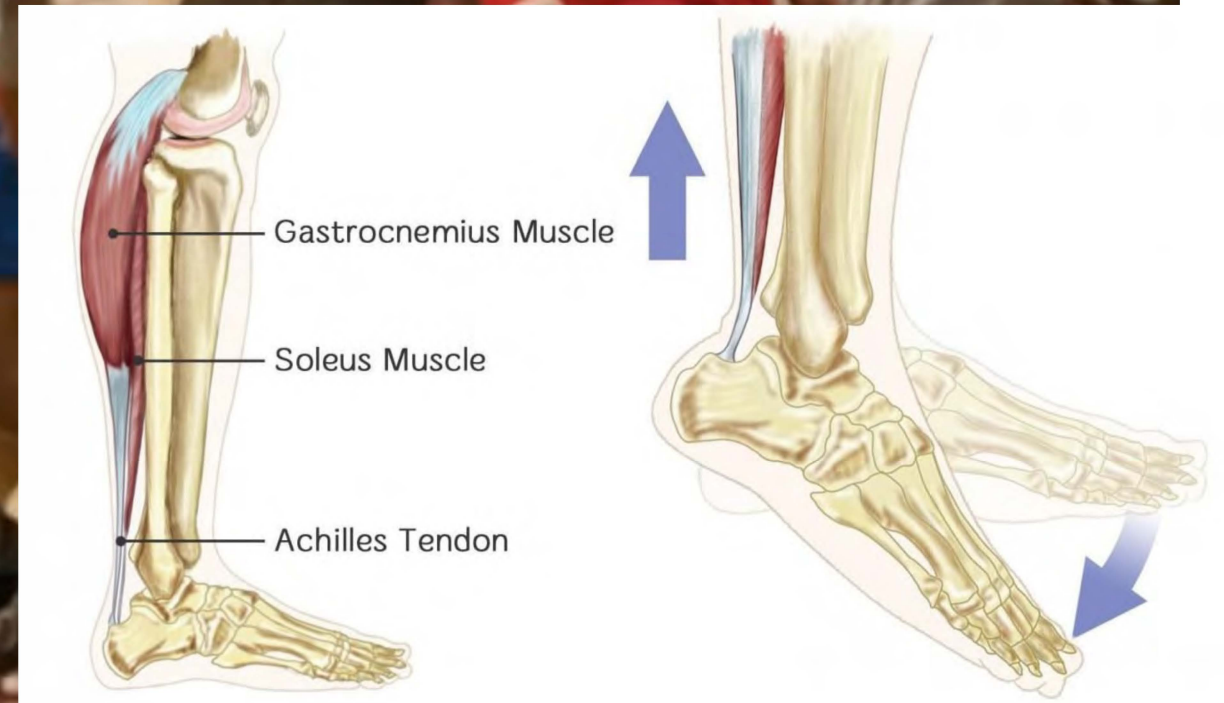


WHAT IS THE ACHILLES TENDON?

The single tendon connects the soleus, gastrocnemius muscle to the calcaneus

The contracting calf muscles lift the heel by this tendon, thus producing a foot action that is basic to walking, running, and jumping

Essential for all movements in basketball



MECHANISM OF INJURY

The most common mechanism of injury is taking off from a stopped position just before toe-off in a dorsiflexed foot



NBA LP	
PHI	41
MEM	60
HALF	

NBA ALL-STAR 2015

RISEING STARS

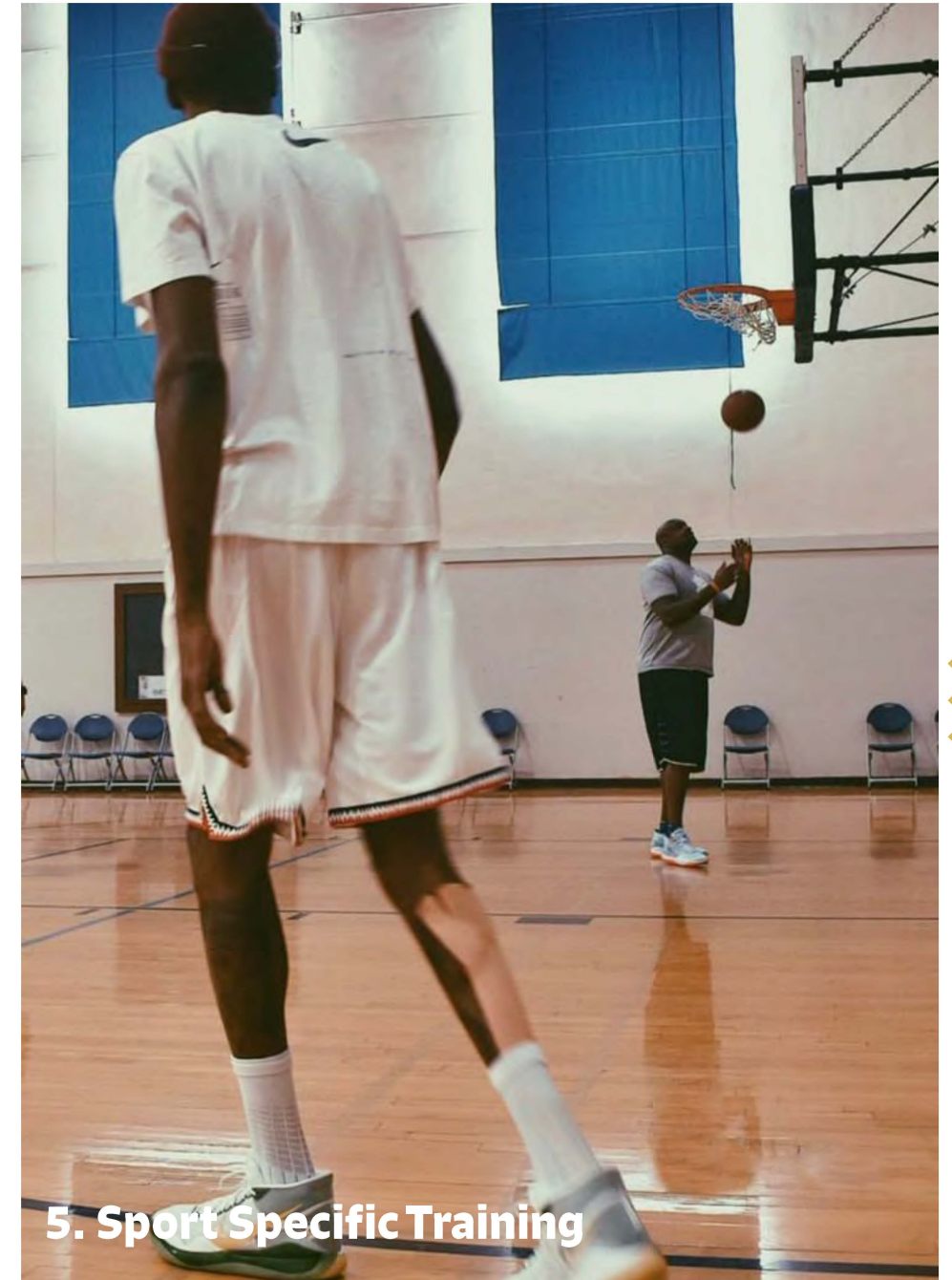
Center in Brooklyn and will air on TNT.



BASKETBALL

RECOVERY PROCESS

A complete rupture usually takes 8-12 months to recover



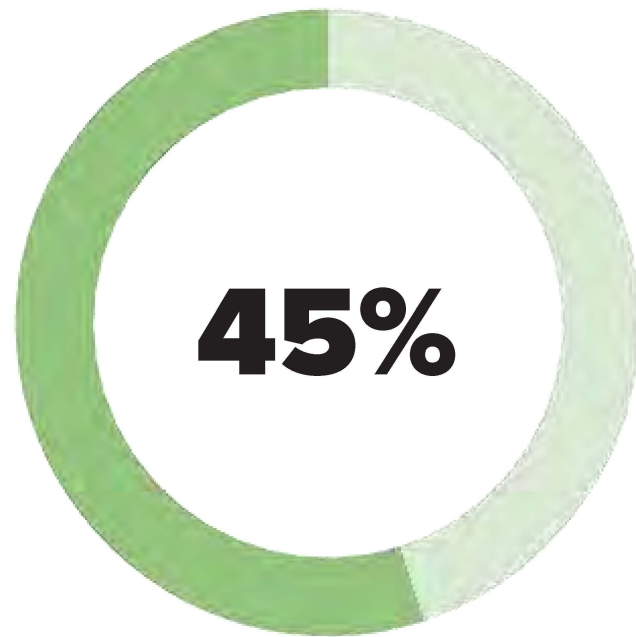
FOOTBALL

**Training cleats for athletes with turf toe problem
(first MTP joint injury)**



WHY THIS TOPIC?

Turf toe has been one of the most common injuries in football since the introduction of the artificial turf.



Reported Injury Rate Unreported & Uninjured

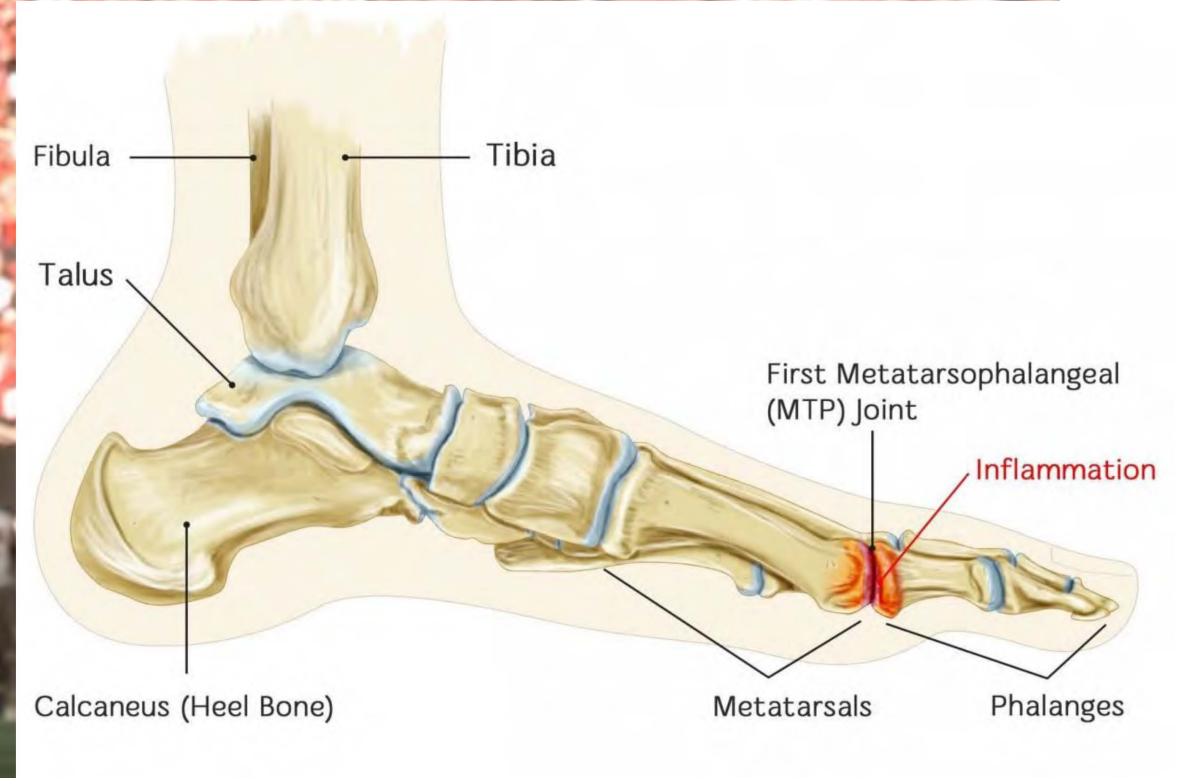
The reported injury rate in professional football players has been as high as **45%**



WHAT IS THE FIRST MTP JOINT?

Most of the stability of the hallux MTP joint comes from the capsule, ligaments, and short flexor complex

Essential for pushing off, sprinting and cutting in football



MECHANISM OF INJURY

FOX NETWORK

Typically turf toe happens when a foot is fixed to the ground, with the heel elevated, and a player lands on the back of the foot, causing injury to the hallux MTP joint. It can also happen without contact.

FOOTBALL

RECOVERY PROCESS

Usually takes 1-2 weeks to recover, severe cases can take over 10 weeks

1. Walker Boots



2. Strength Training



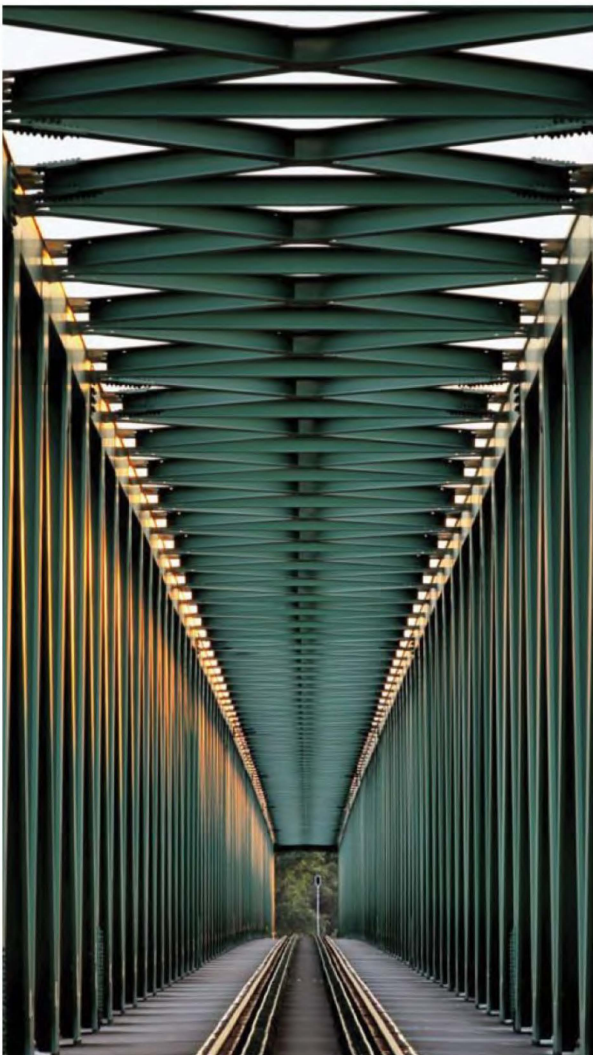
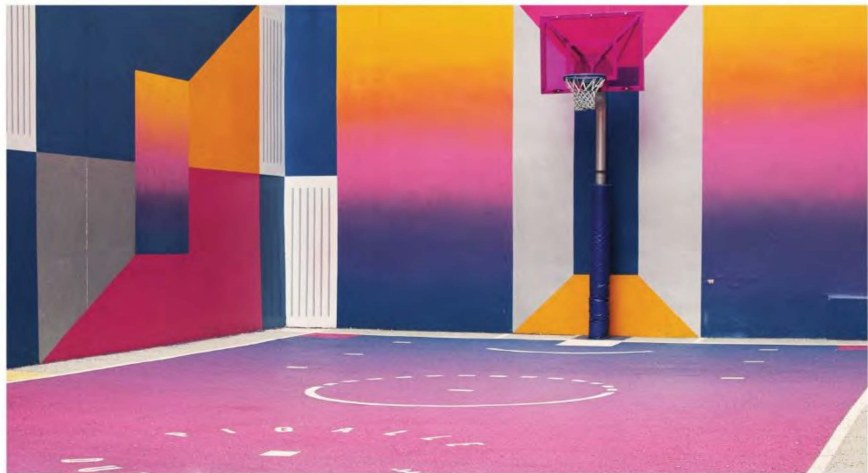
3. Additional Taping



4. Sport Specific Training



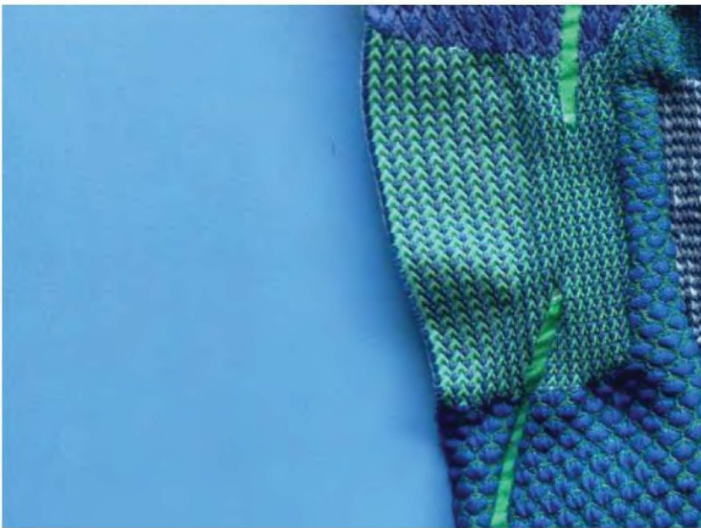
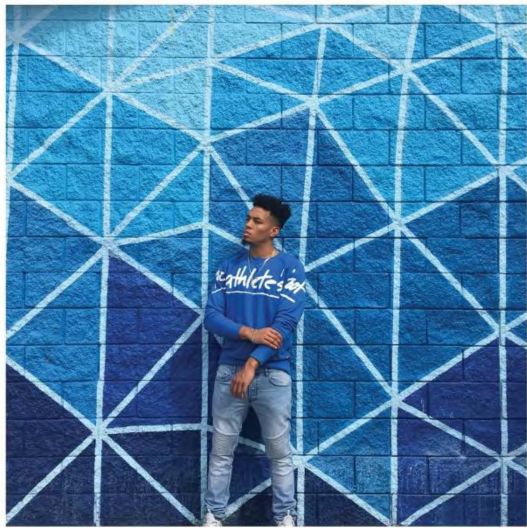
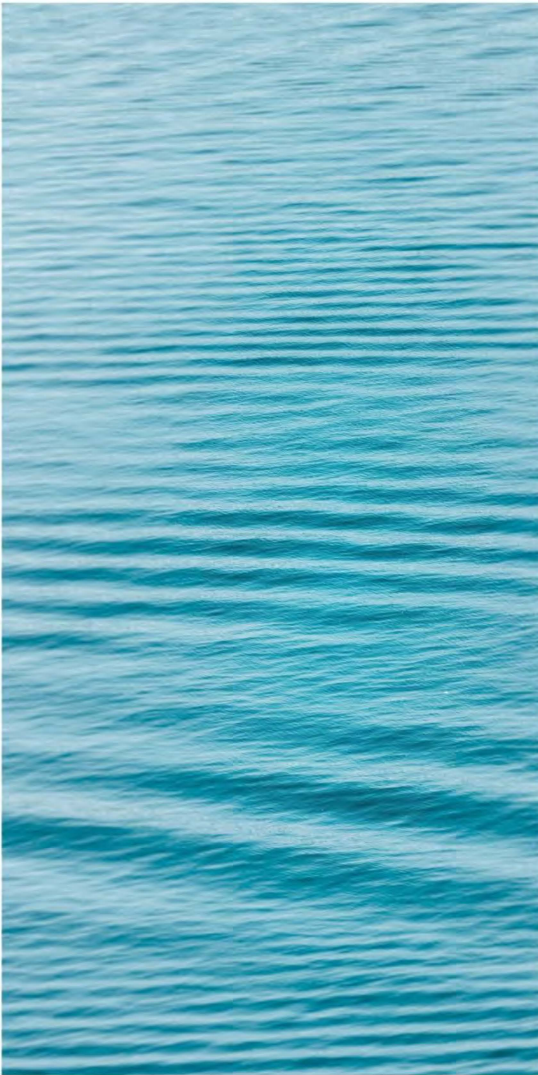
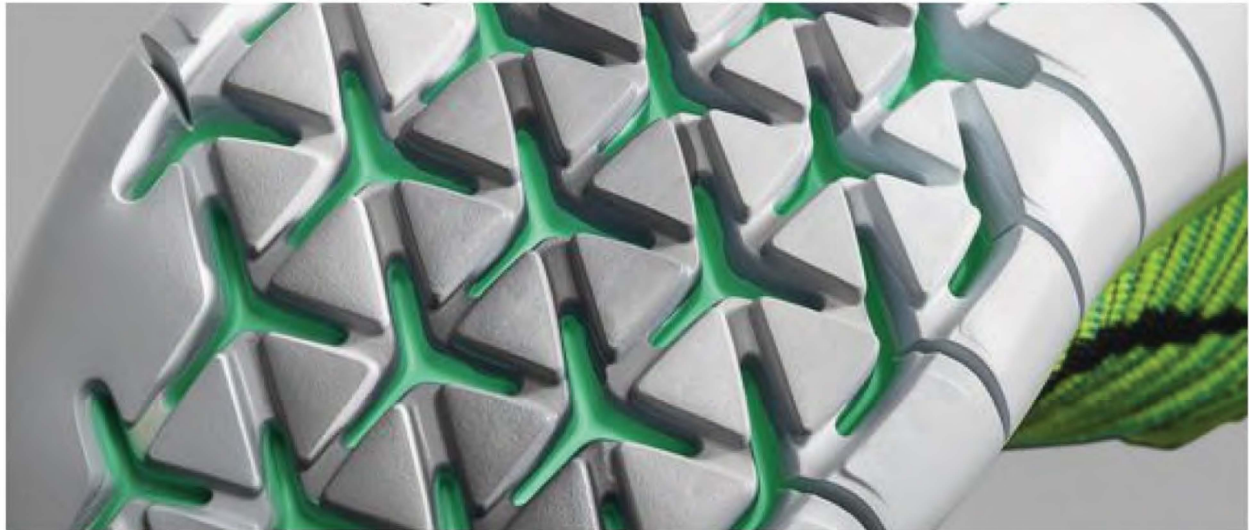
MOOD BOARD



RESILIENCE · STABILITY · COMFORT

/// BASKETBALL

MOOD BOARD

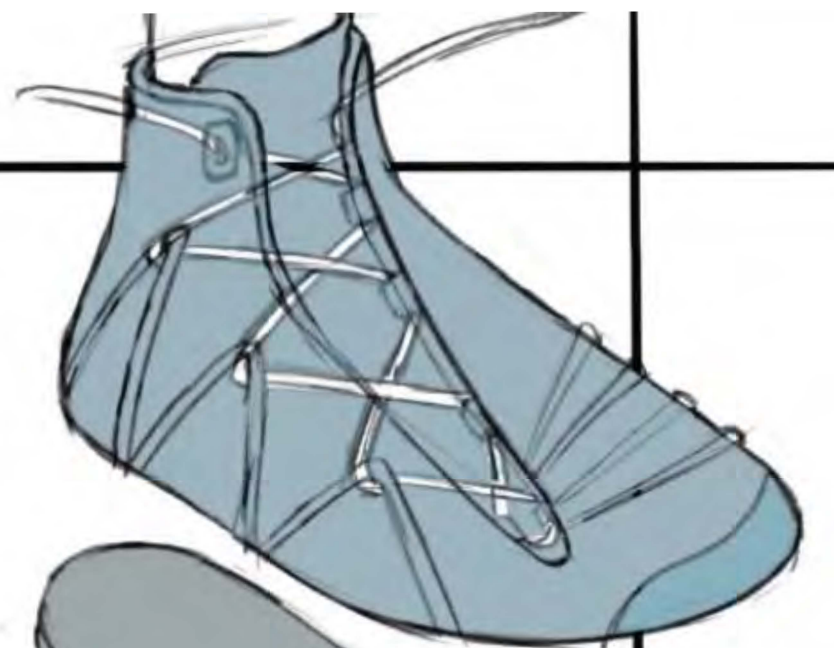


RESILIENCE · SUPPORT · COMFORT

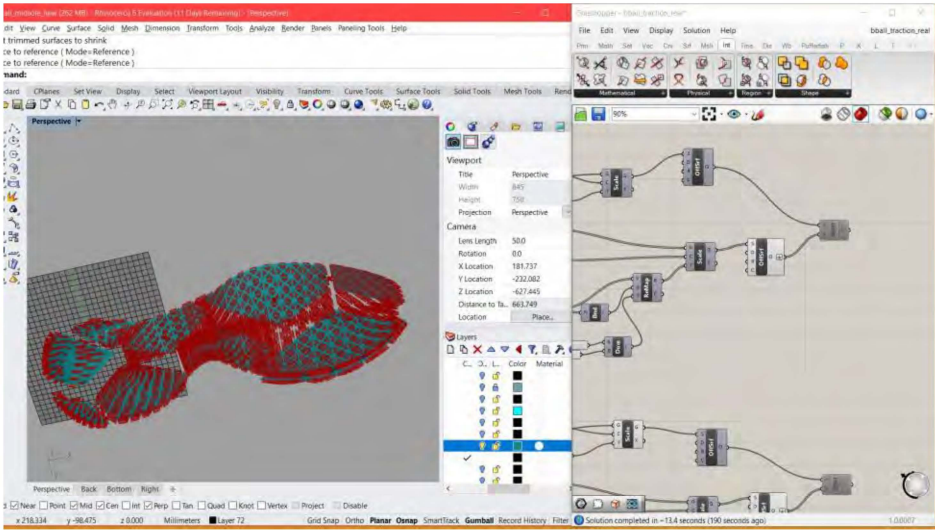
IDEATION

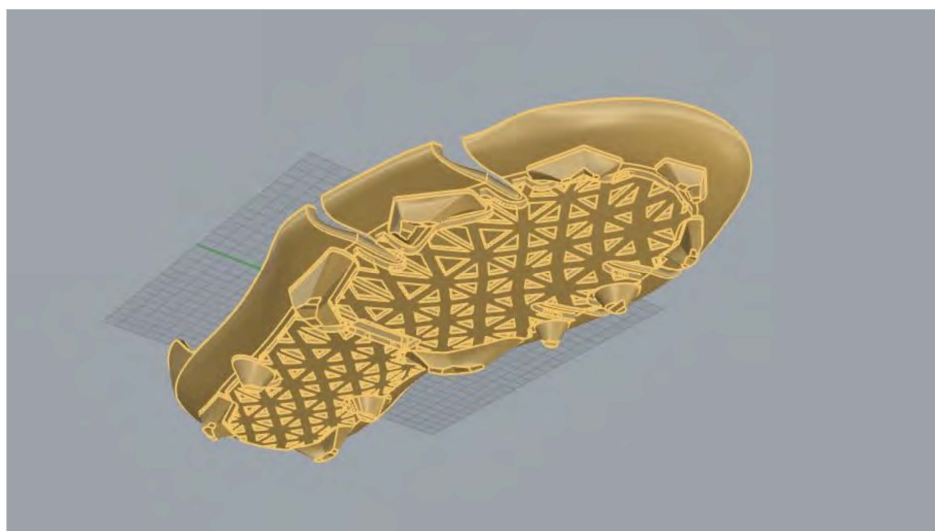
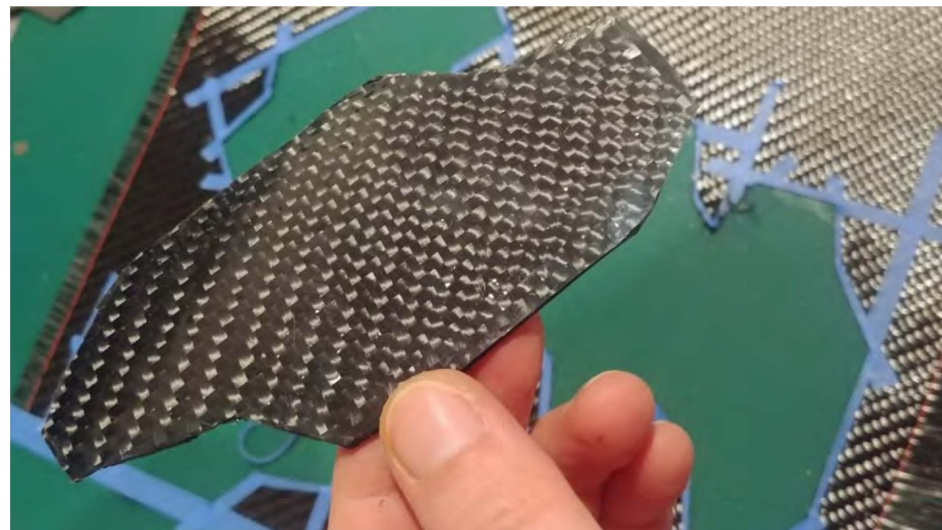


IDEATION



PROTOTYPING







RESURGENCE

Post Achilles Injury Recovery Training Footwear
for elite/subelite basketball players

LAST Specifically tuned to help alleviate pressure at
Achilles Tendon and facilitates smoother movements



Raised heel drop:

Reduces pressure at Achilles tendon,
also provides better propulsion

Raised toe spring:

Allows smoother toe off

PARTS & PURPOSES







RESURGENCE

Post MTP joint Injury Recovery Training Cleats

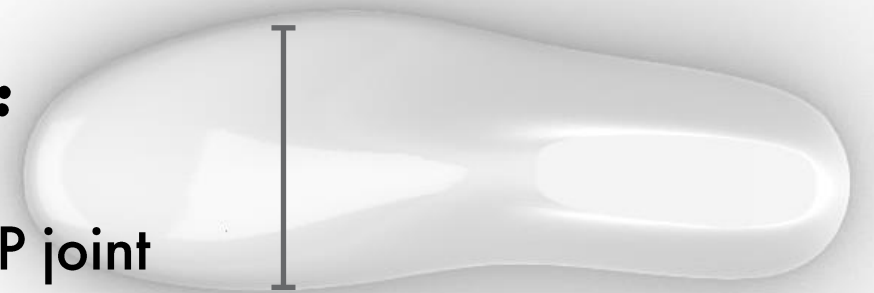
for elite/subelite football players

LAST

Specificly tuned to help alleviate pressure at injured area

Widened forefoot width:

Anatomical design avoids unnecessary stress at the MTP joint



Reduced heel drop and toe spring:

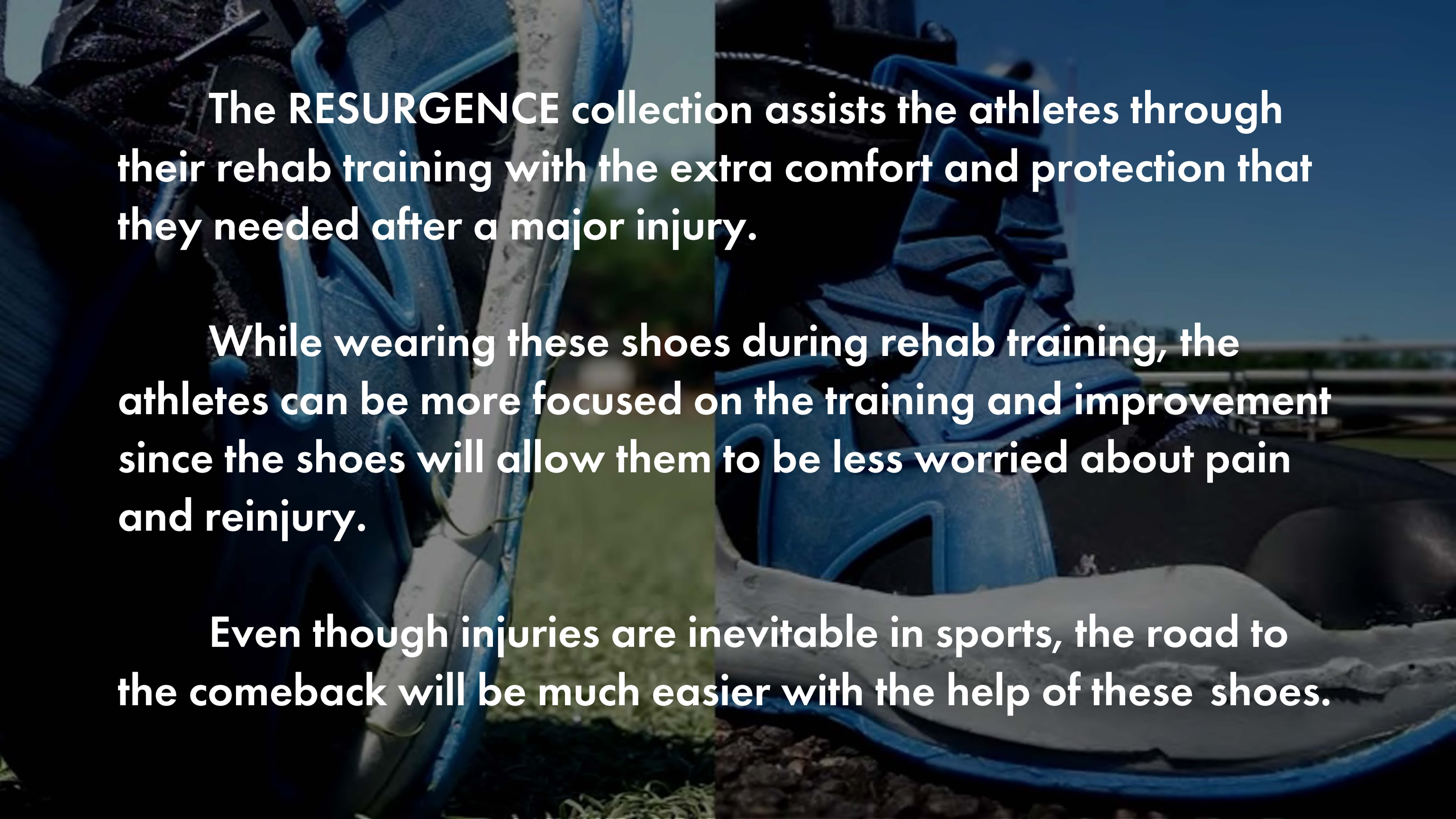
Allowing the foot to stay at natural position; Reduces pressure at the forefoot by distributing the force more evenly along the foot



PARTS & PURPOSES





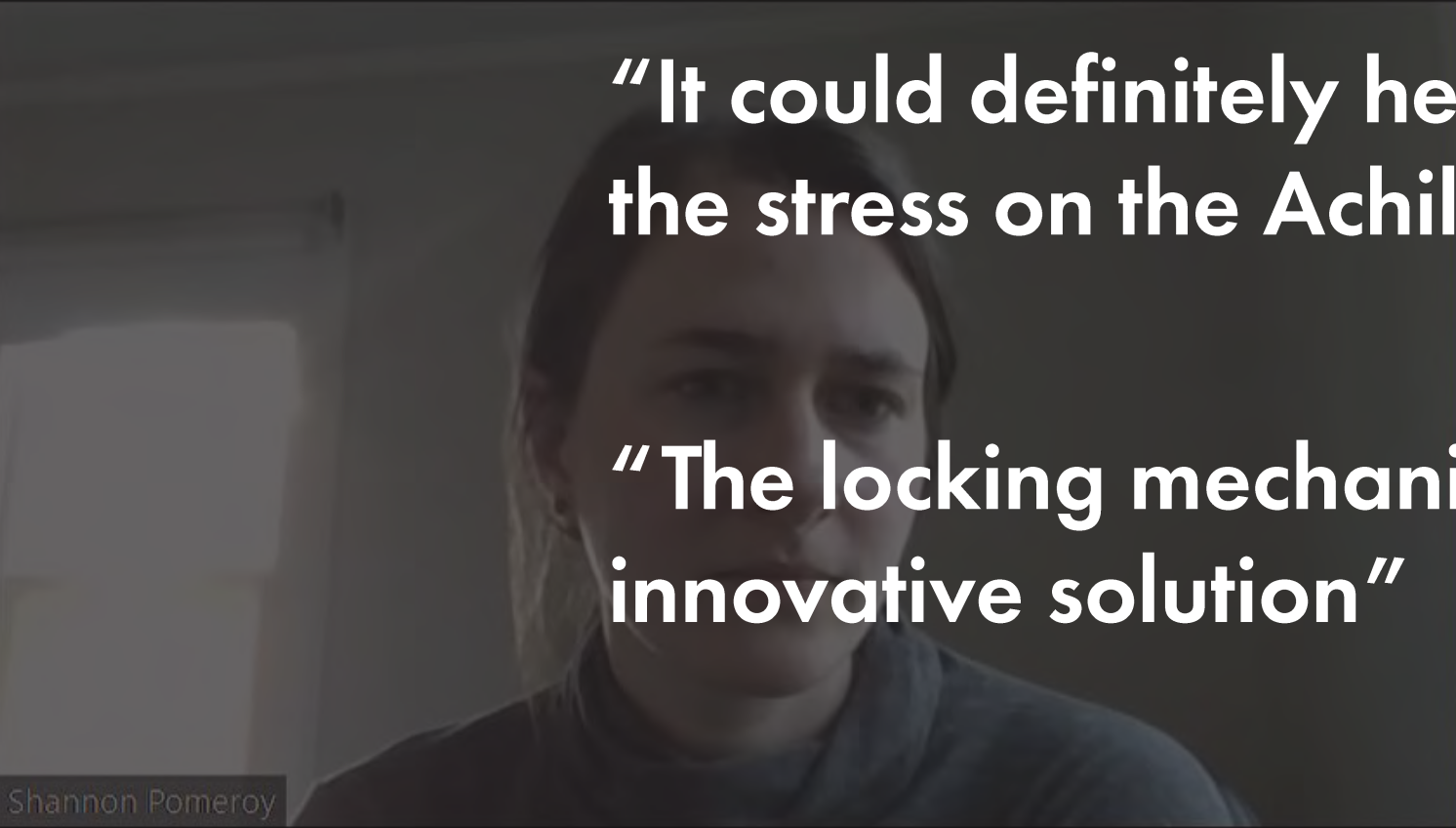


The RESURGENCE collection assists the athletes through their rehab training with the extra comfort and protection that they needed after a major injury.

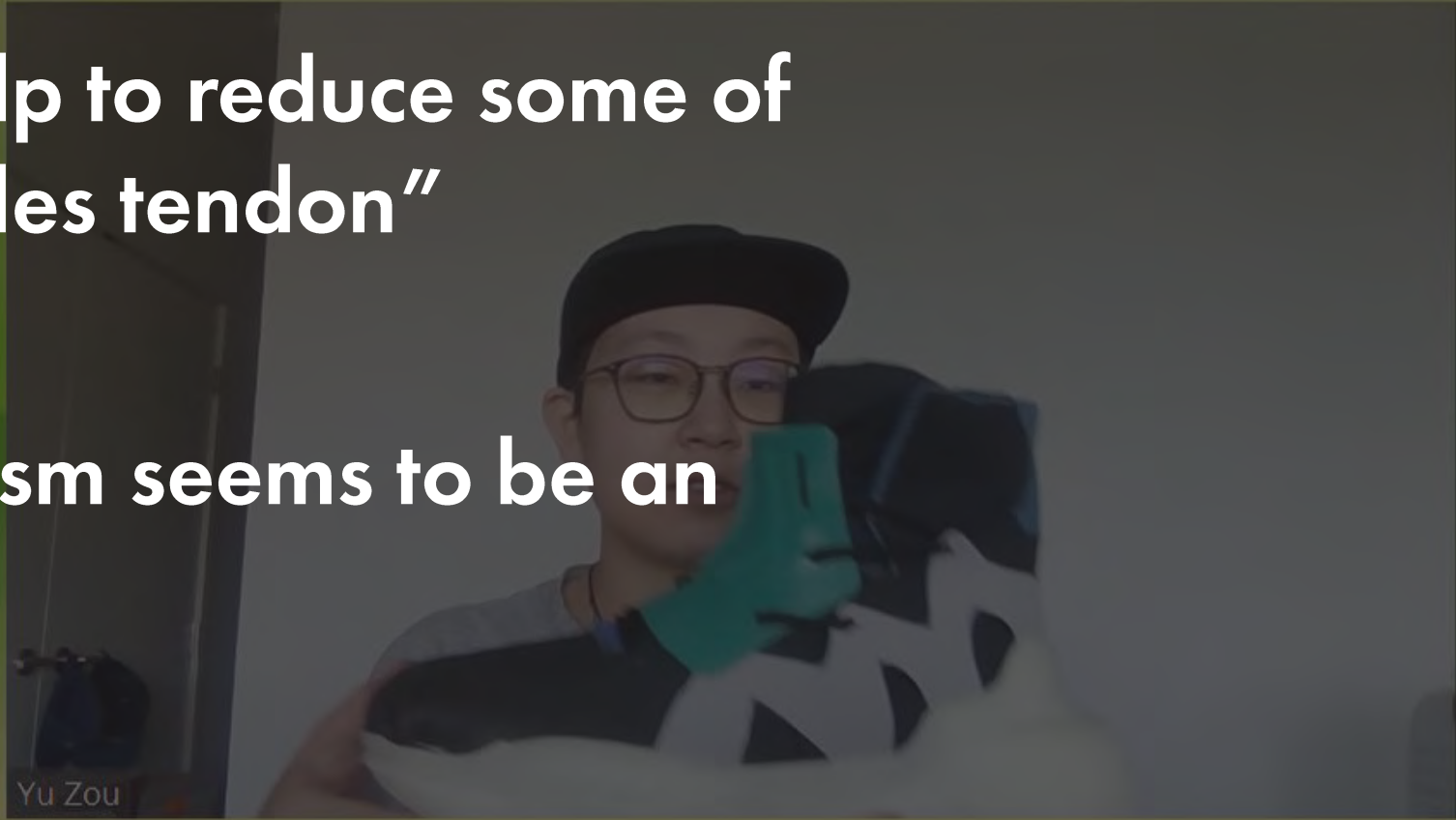
While wearing these shoes during rehab training, the athletes can be more focused on the training and improvement since the shoes will allow them to be less worried about pain and reinjury.

Even though injuries are inevitable in sports, the road to the comeback will be much easier with the help of these shoes.

EXPERTS INSIGHTS

A video frame showing Shannon Pomeroy, a woman with dark hair, speaking. The text is overlaid on the right side of the frame.

“It could definitely help to reduce some of the stress on the Achilles tendon”

A video frame showing Yu Zou, a man wearing a black cap and glasses, holding a green object. The text is overlaid on the left side of the frame.

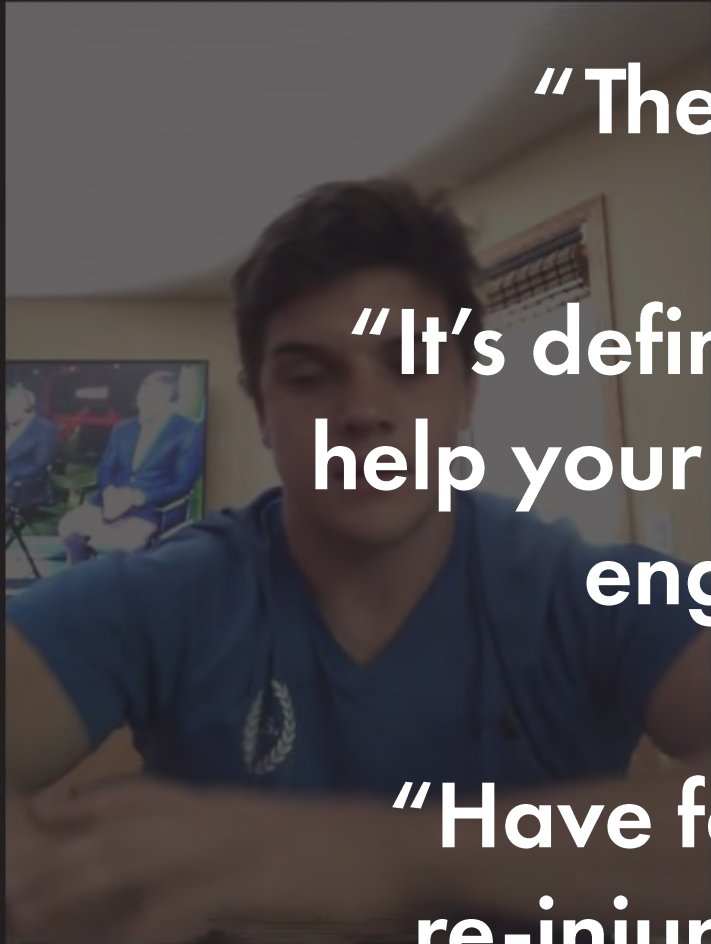
“The locking mechanism seems to be an innovative solution”

Shannon Pomeroy

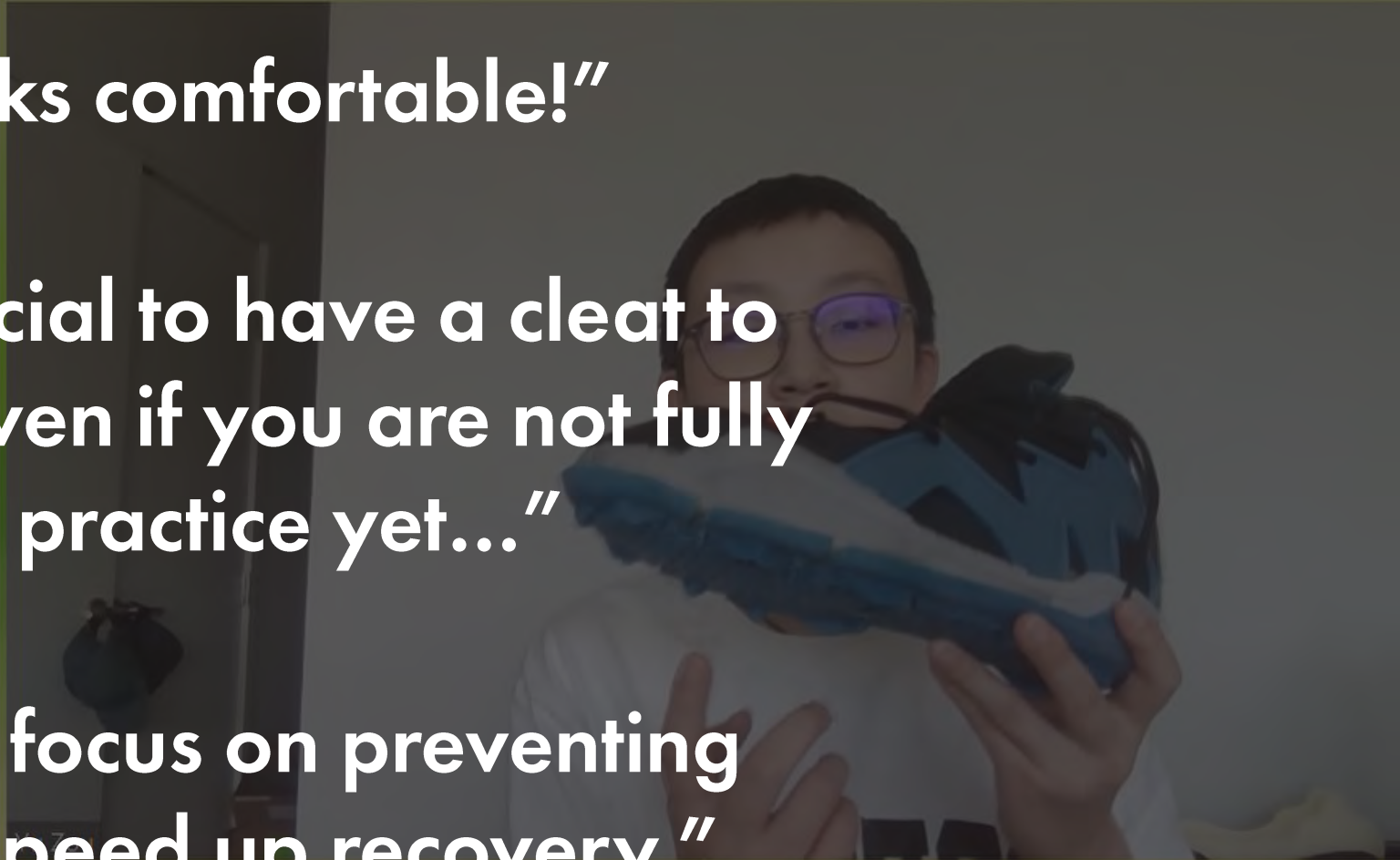
Yu Zou

-- **Shannon Pomeroy,**
*Nike Explore Team (ETW/FLEX),
Applied Product Connection*

VALIDATION BY ATHLETE



"The bottom looks comfortable!"



"It's definitely beneficial to have a cleat to help your recovery, even if you are not fully engaged in the practice yet..."

"Have features that focus on preventing re-injury can help speed up recovery."

-- **James Klecker**, LB at University of St. Thomas

QUESTIONS?



THANK YOU!

An illustration of a doctor in a blue lab coat and goggles, using a surgical tool to work on a patient's foot. The doctor's hands are visible, and the patient's foot is the focus of the procedure. The background is dark and moody.

Recovery Training Shoes for Achilles & Turf Toe Injury

Project Overview:

Designing two pairs of shoes for elite/ sub-elite basketball and football athletes to wear during rehab training after a major injury, or when training in the game season while suffering from chronic Achilles and turf toe problems.

University of Oregon
Sports Product Design
Yu Zou

Why Injury Recovery Training Shoes?



**Acute/ overuse injuries are inevitable in high performance sports.
A smooth rehab process is essential for the athlete to get back to the competition successfully.**

**However, there is no sports specific rehab training shoes in the market
to help the athletes through the process. Athletes have to switch into
regular footwear from walker boots with no transitional product.**

A basketball player in a blue and yellow Golden State Warriors jersey, number 30, is sitting on the wooden floor of a basketball court. He is holding his right leg, which is bent and appears to be in pain. He is wearing white socks and white sneakers with black laces. The background shows a crowd of spectators in a stadium setting.

PROJECT 1:

Basketball Training Shoes for Athletes Who had Achilles Injuries (Achilles Tendon Rupture/ Achilles Tendinopathy)

Why This Topic?

One of the most devastating injuries which affects performance for the remainder of player's career



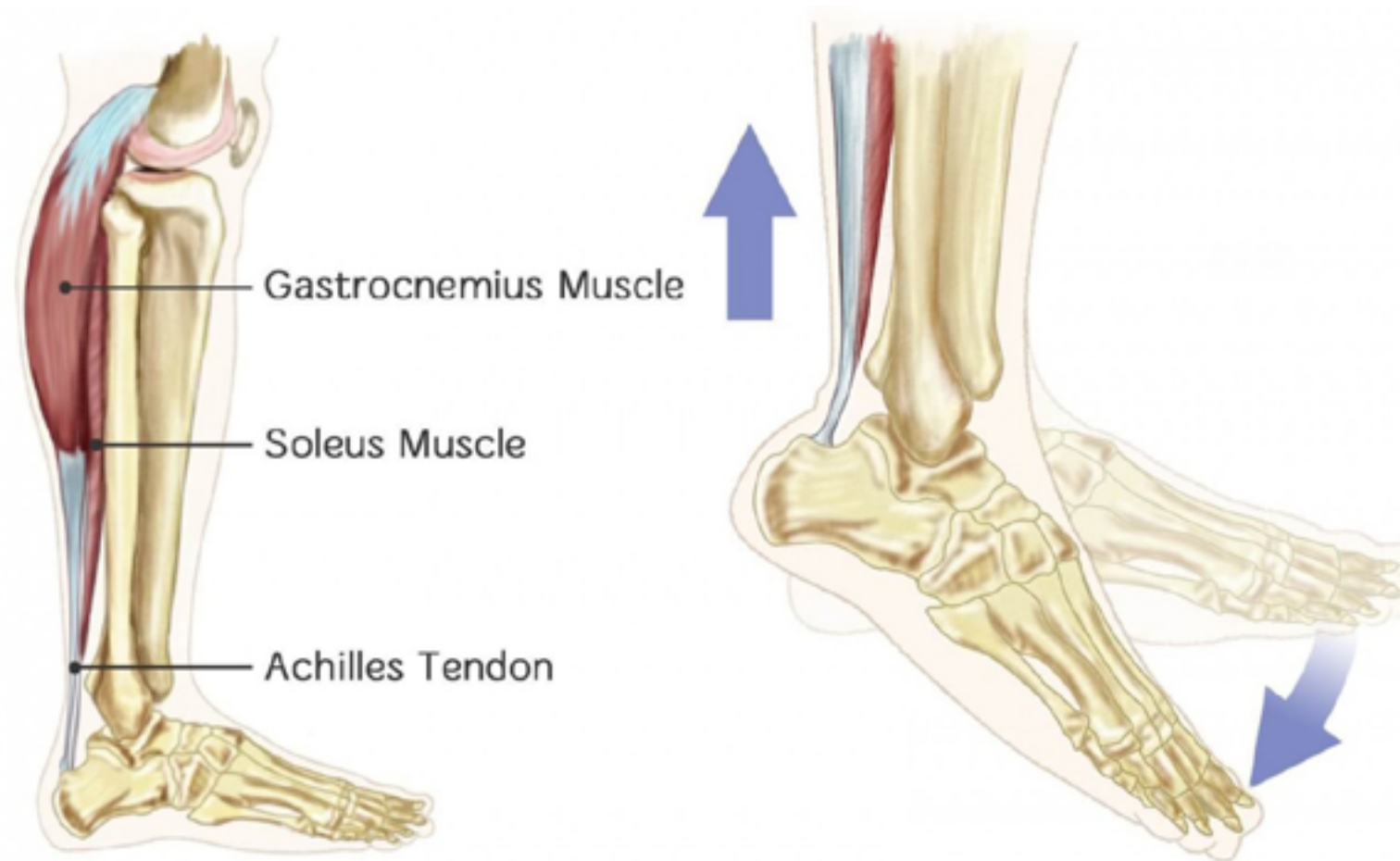
According to a 2016 study: 14% of NBA players were unable to return to function/ play after Achilles tendinopathy, and that those who were able to return did so at a decreased level of performance

What is the Achilles Tendon?

The single tendon connects the soleus, gastrocnemius muscle to the calcaneus

The contracting calf muscles lift the heel by this tendon, thus producing a foot action that is basic to walking, running, and jumping

Essential for all movements in basketball

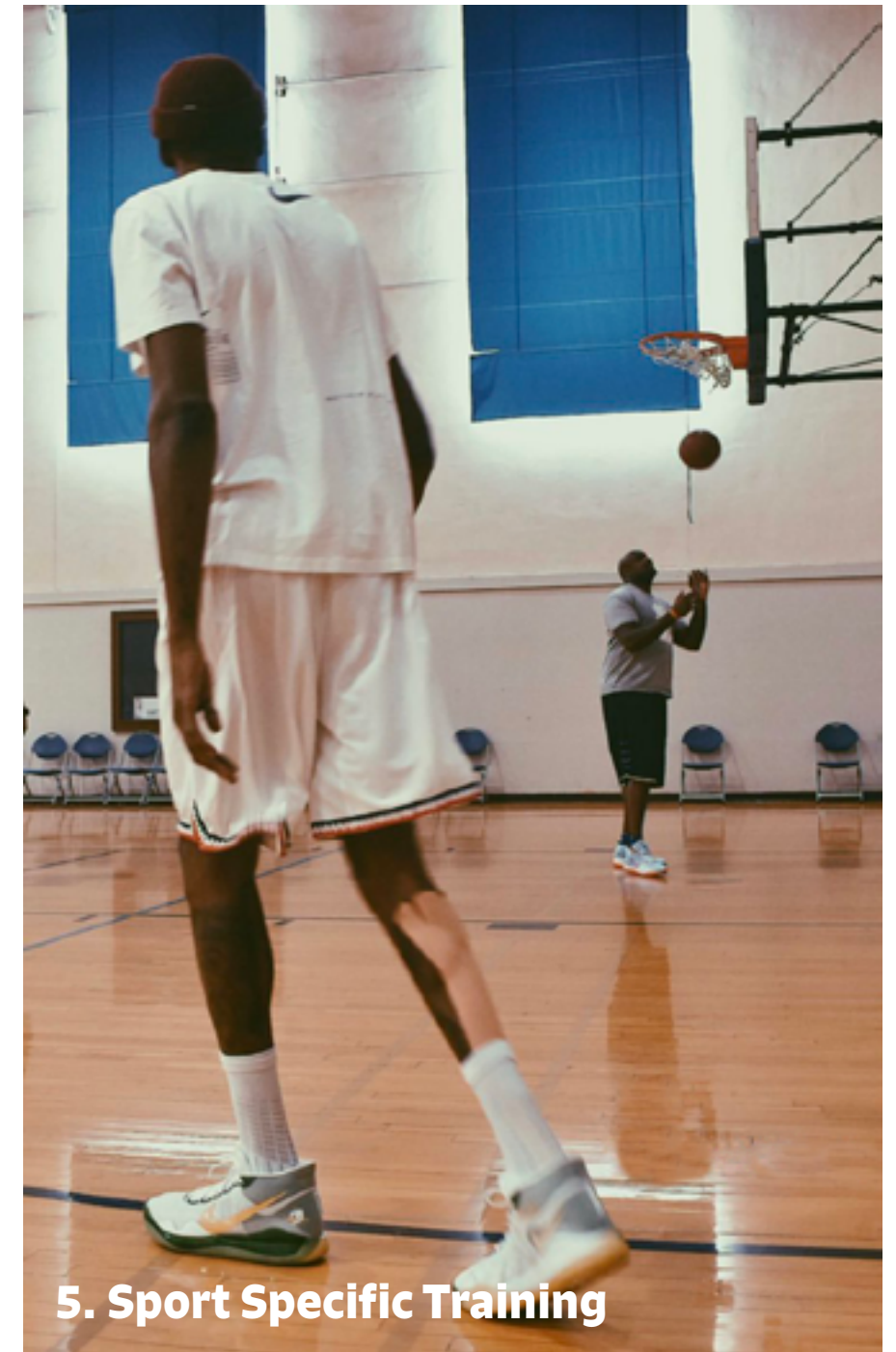


Mechanism of Injury



The most common mechanism of injury is taking off from a stopped position just before toe-off in a dorsiflexed foot

Recovery Process A complete rupture usually takes 8-12 months to recover



Experts Insights



Name: Shannon Pomeroy
Nike Explore Team (ETW/FLEX)

Applied Product Connection

Insights: Be aware of the pressure points when adding more elements onto the shoes. Look up the amount of force that is required to tear the tendon. Be aware of the chain reactions between body parts.



Name: Justin Silverman
Adidas

Athlete Services

Insights: The Achilles tendon is sensitive after the surgery, therefore a softer and less angled heel rake is important. More shock absorption also helps to reduce the stress.



Design Brief

Basketball training shoes designed to help NBA/ NCAA athletes who are recovering from Achilles Injuries.

Consumer:

Elite/Sub-Elite Male Basketball Players

Environment:

Indoor Hardwood Floor

Season of Delivery:

Fall 2022

Retail Price: \$200

FOB: \$50

Customizable Option: \$350

FOB: \$87.5



Design Direction

Key Words:

Range of Motion; Protection; Stability

Features & Benefits:

Adjustable Flexion Restriction System prevents accidental over-stretching of the tendon

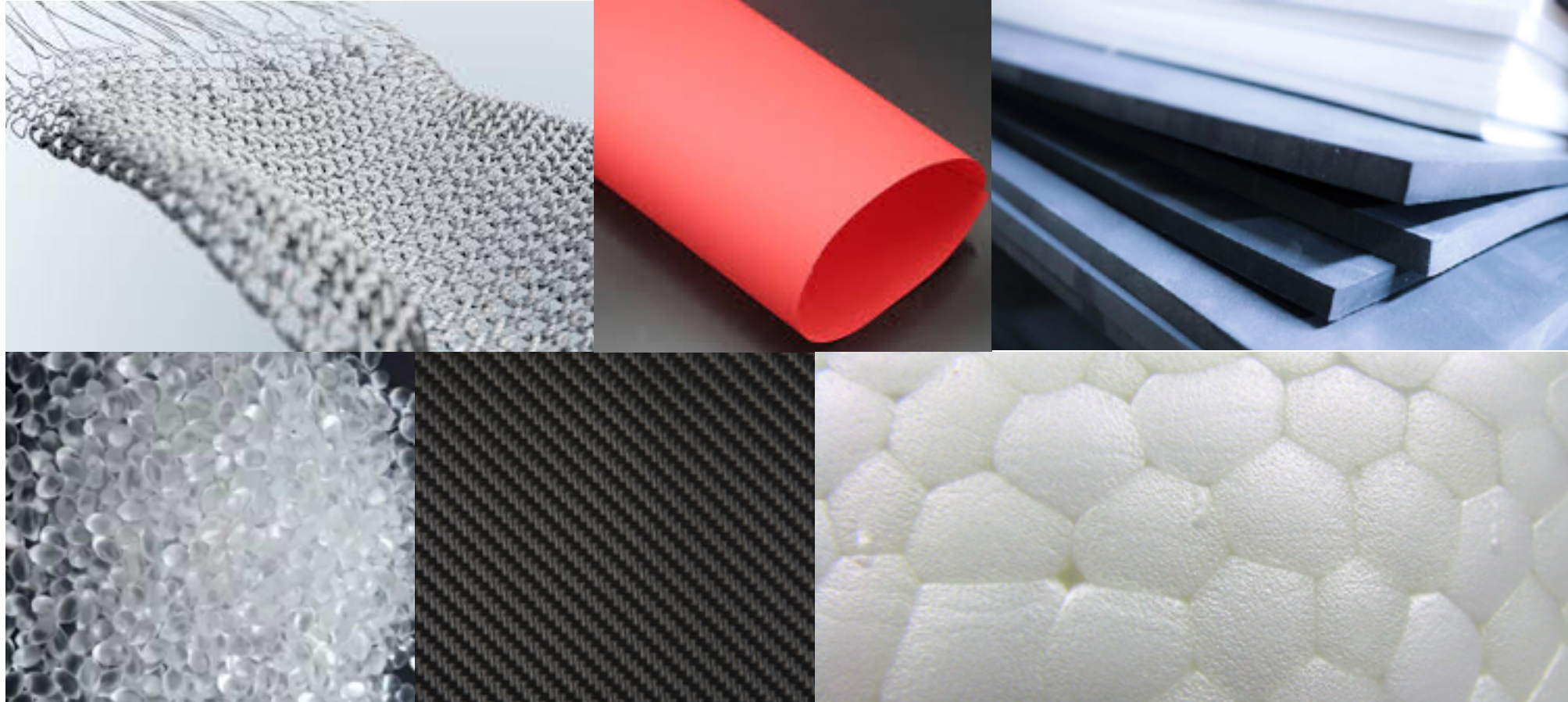
Higher Heel-Toe Offset reduces stress on the Achilles tendon

Increased Heel & Toe Spring offers a smoother transition for each step

Extra Cushioning at the heel lessens shock to the tendon

Wider Midsole provides more stability

Materials Direction



4D Knitting Upper
TPU Hot Melt Overlay
EVA & ETPU Foam
TPU Heel Counter
Carbon Fiber Plate

PROJECT 2:
Football training cleats for athletes with turf toe problem
(first MTP joint injury)

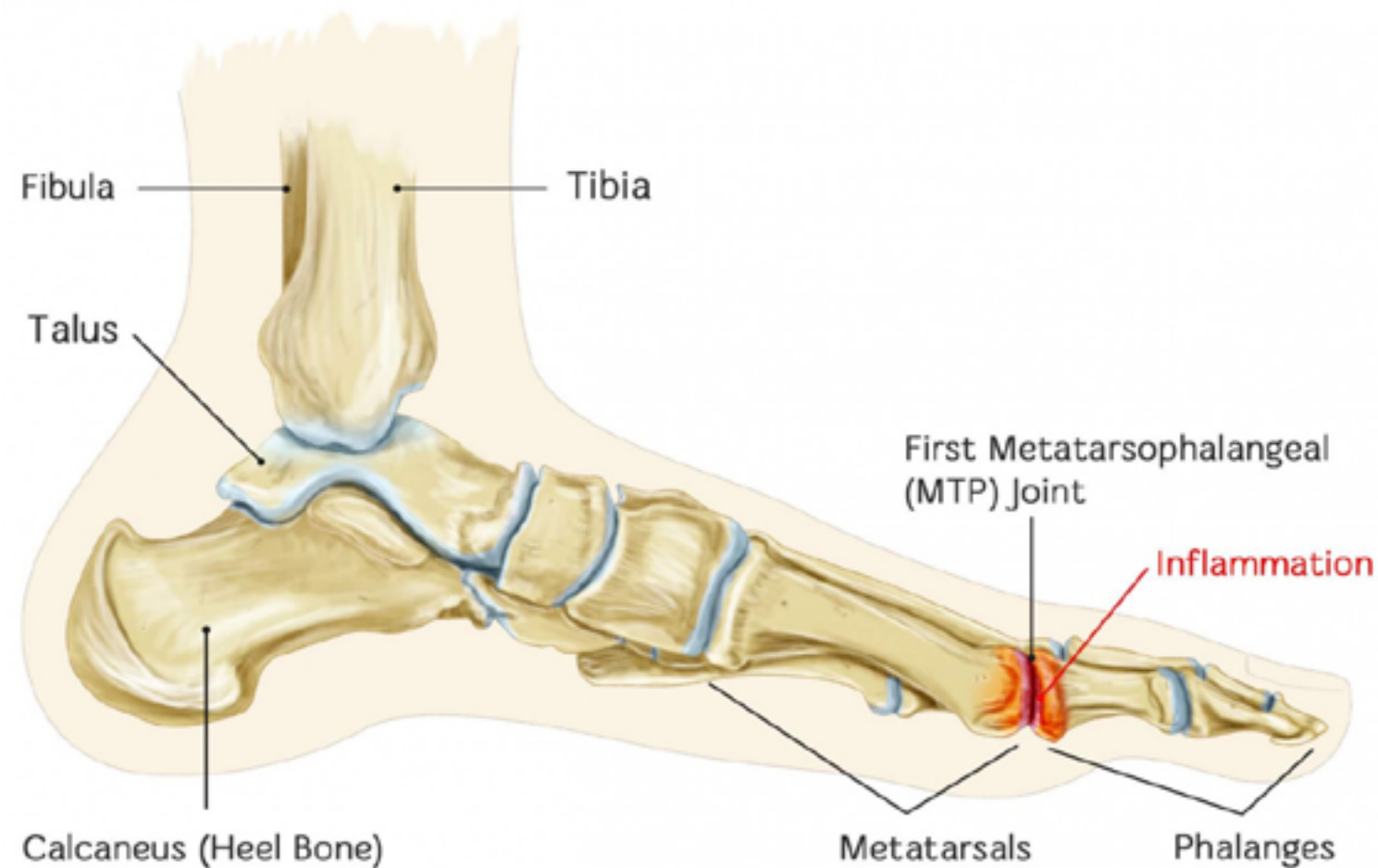
Why This Topic?

Turf toe has been one of the most common injuries in football since the introduction of the artificial turf. The reported injury rate in professional football players has been as high as 45%



What is the First MTP Joint?

Most of the stability of the hallux MTP joint comes from the capsule, ligaments, and short flexor complex
Essential for pushing off, sprinting and cutting in football

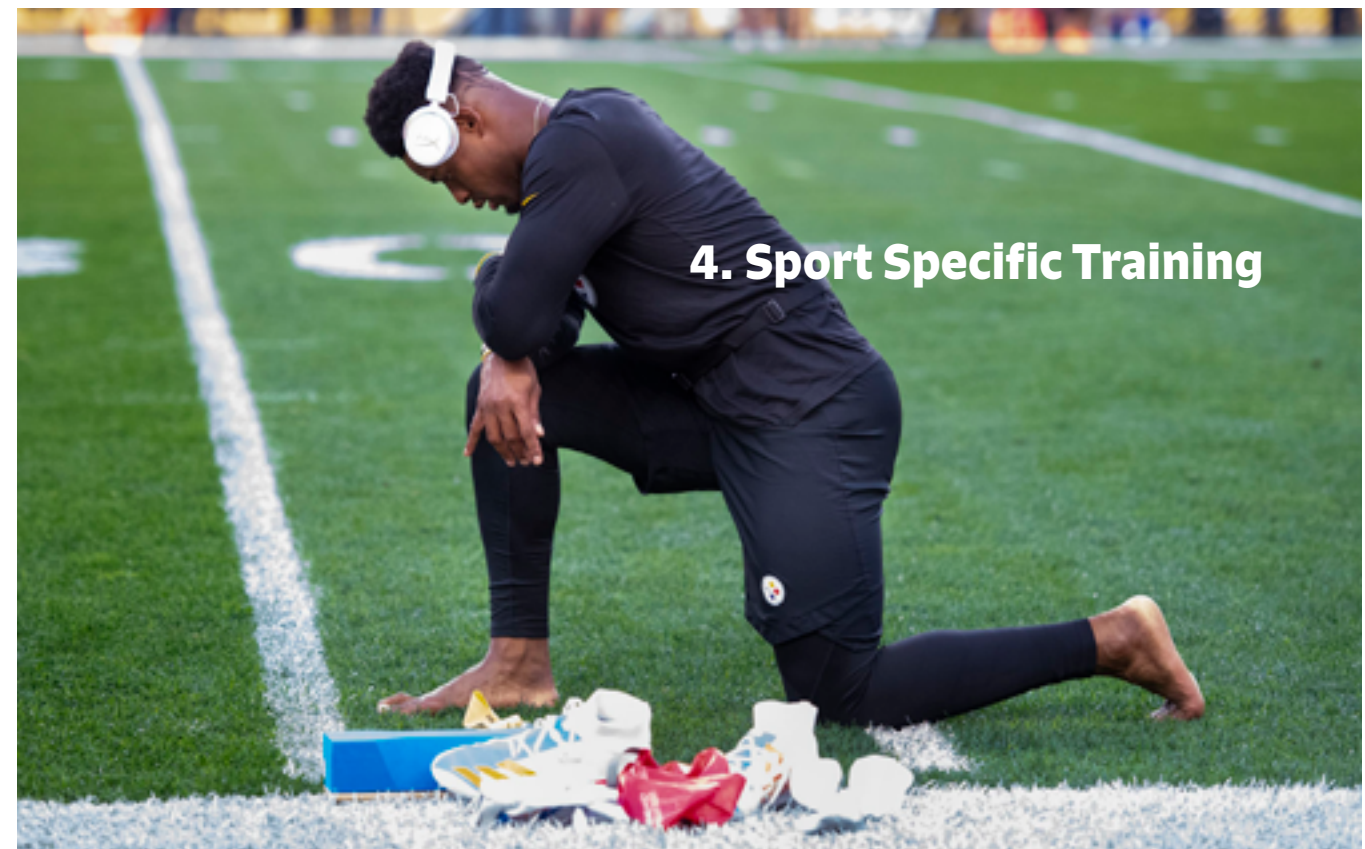


Mechanism of Injury



Typically turf toe happens when a foot is fixed to the ground, with the heel elevated, and a player lands on the back of the foot, causing injury to the hallux MTP joint. It can also happen without contact.

Recovery Process Usually takes 1-2 weeks to recover, severe cases can take over 10 weeks



Experts Insights



Name: Shannon Pomeroy
Nike Explore Team (ETW/FLEX)
Applied Product Connection

Insights: Look at track spike designs for different activities to gain inspiration for stud size and placement. Be aware of the optimal balance of traction and slippage.



Name: Eric Sterner
Adidas
Senior Athlete Services Manager

Insights: Key point to consider: Heel & Toe Spring; Amount of traction; Stiffness of the plate; Interaction between different parts of the foot.

Design Brief

Football training cleats designed to help NFL/ NCAA athletes who are recovering from turf toe Injuries

Consumer:

Elite/Sub-Elite Male Football Players

Environment:

Indoor/Outdoor Artificial Turf

Season of Delivery:

Fall 2022

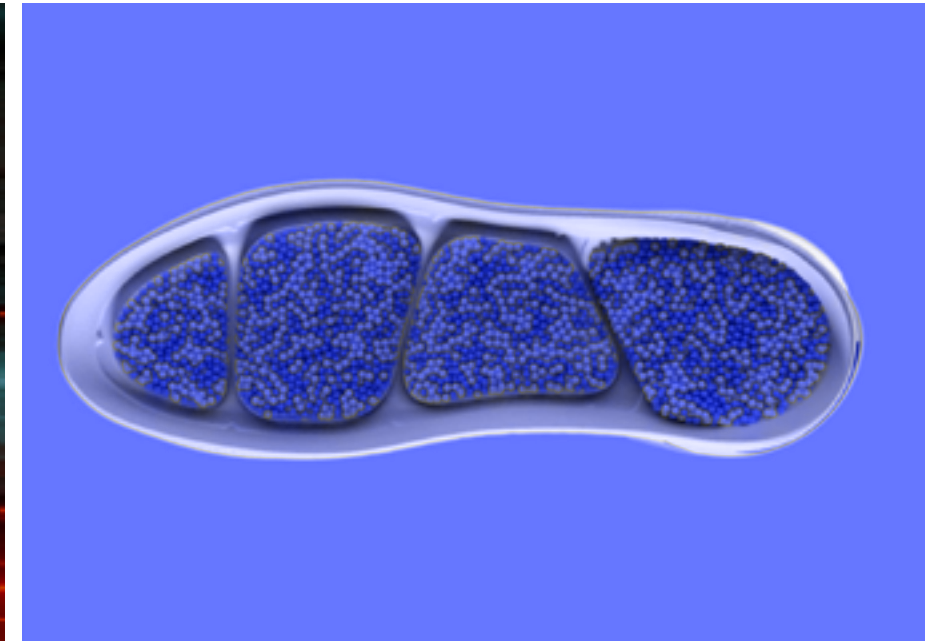
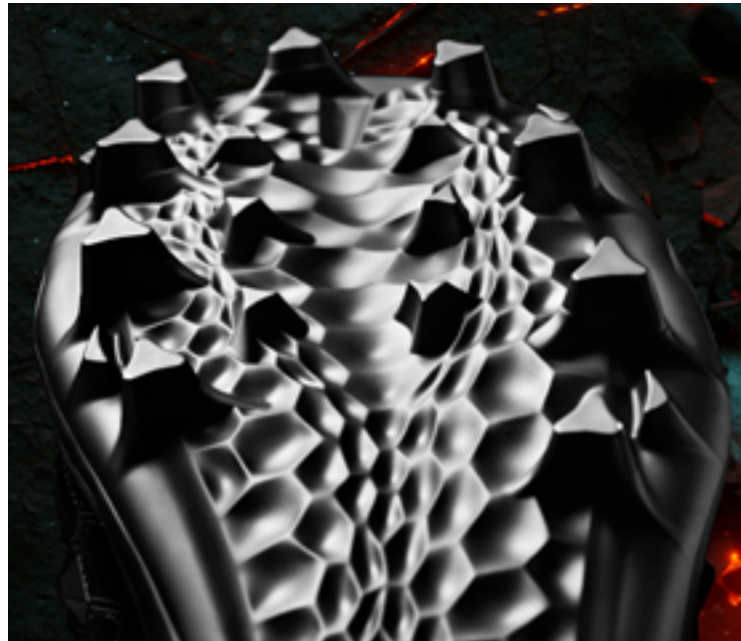
Retail Price: \$160

FOB: \$40

Customizable Option: \$300

FOB: \$75





Design Direction

Key Words:

Range of Motion; Comfort; Support

Features & Benefits:

Flexion Restriction System at Forefoot prevents accidental hyperextension of the joint

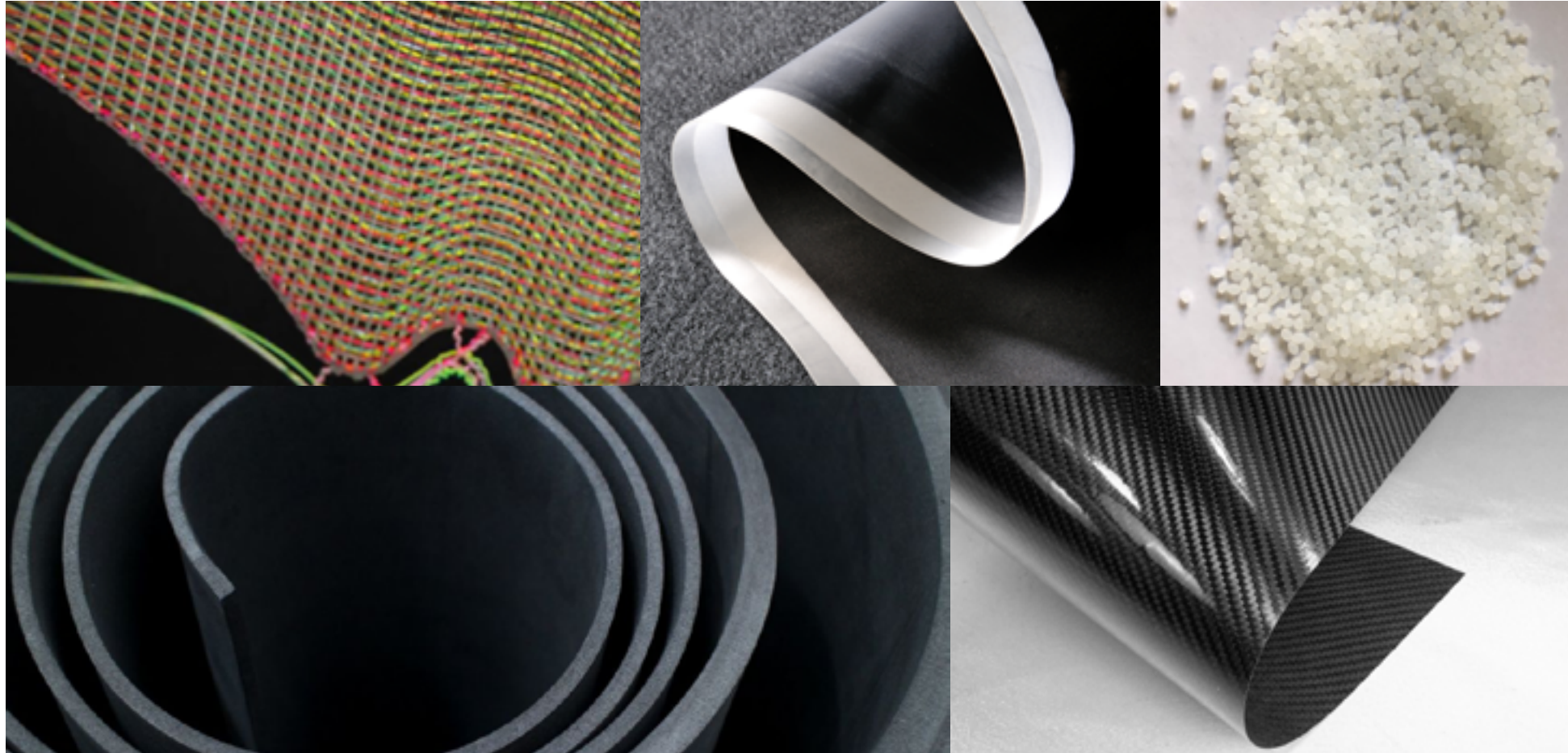
Added Foam Midsole provides cushioning for the forefoot.

Decreased Toe Spring allows the foot to rest in the natural position

Wider Toebox avoids squishing the toes, also gives room for extra taping on the foot

Strategic Cleat Design reduces stress on the MTP joint

Materials Direction



4D Knitting Upper
TPU Hot Melt Overlay
TPU Heel Counter & Plate
EVA Midsole
Carbon Fiber Plate

Inspirations



Ideation

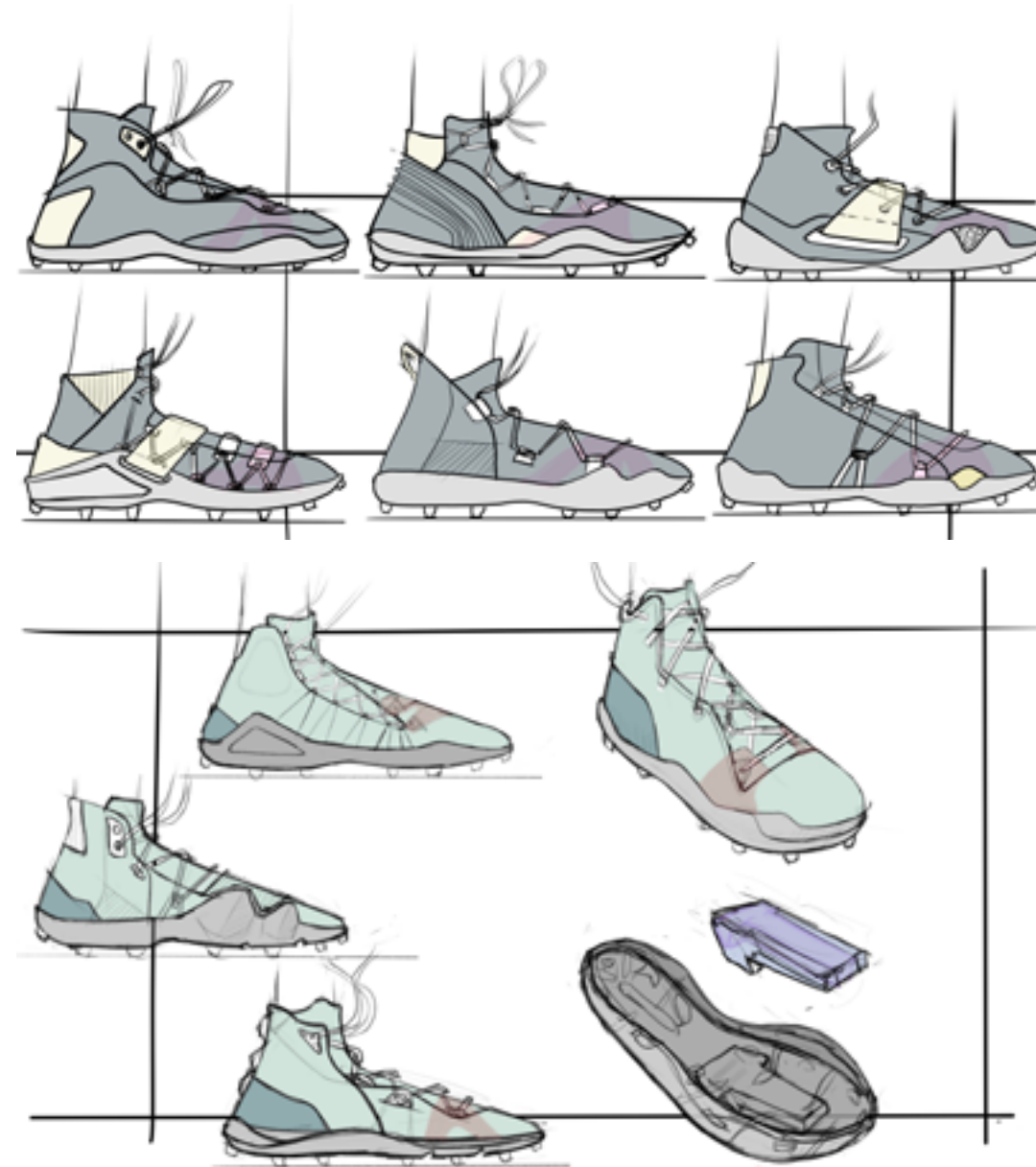
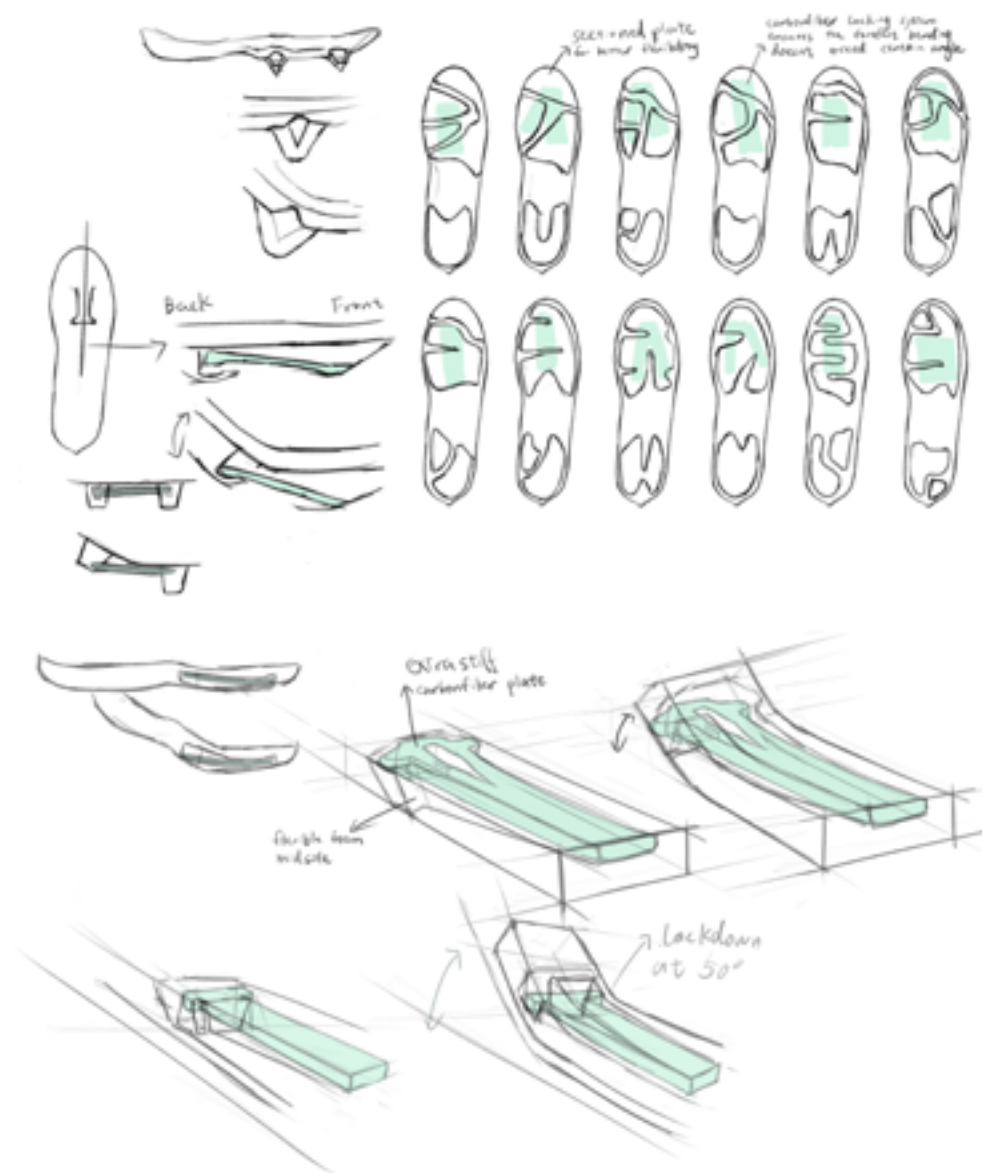
Basketball

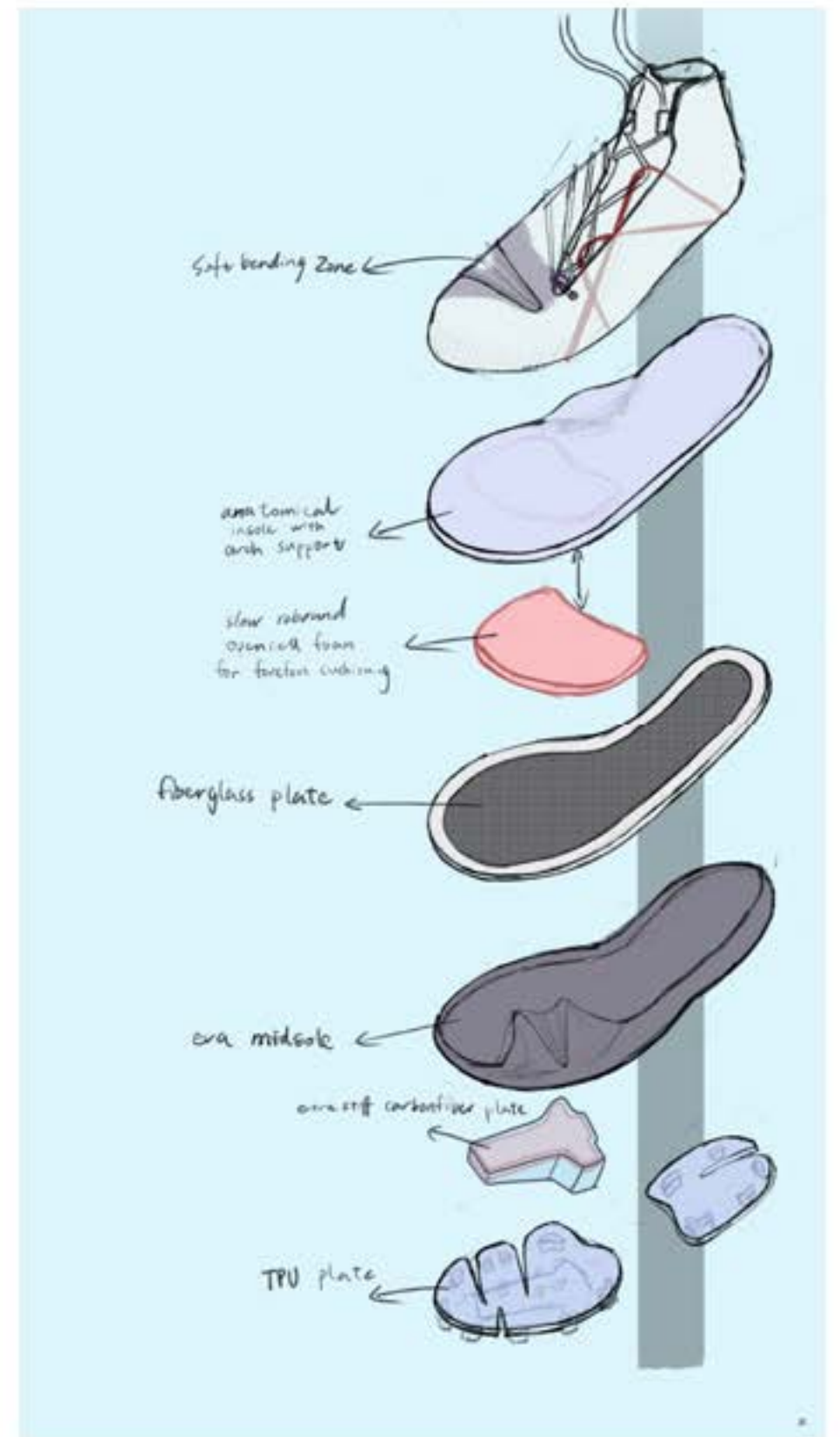
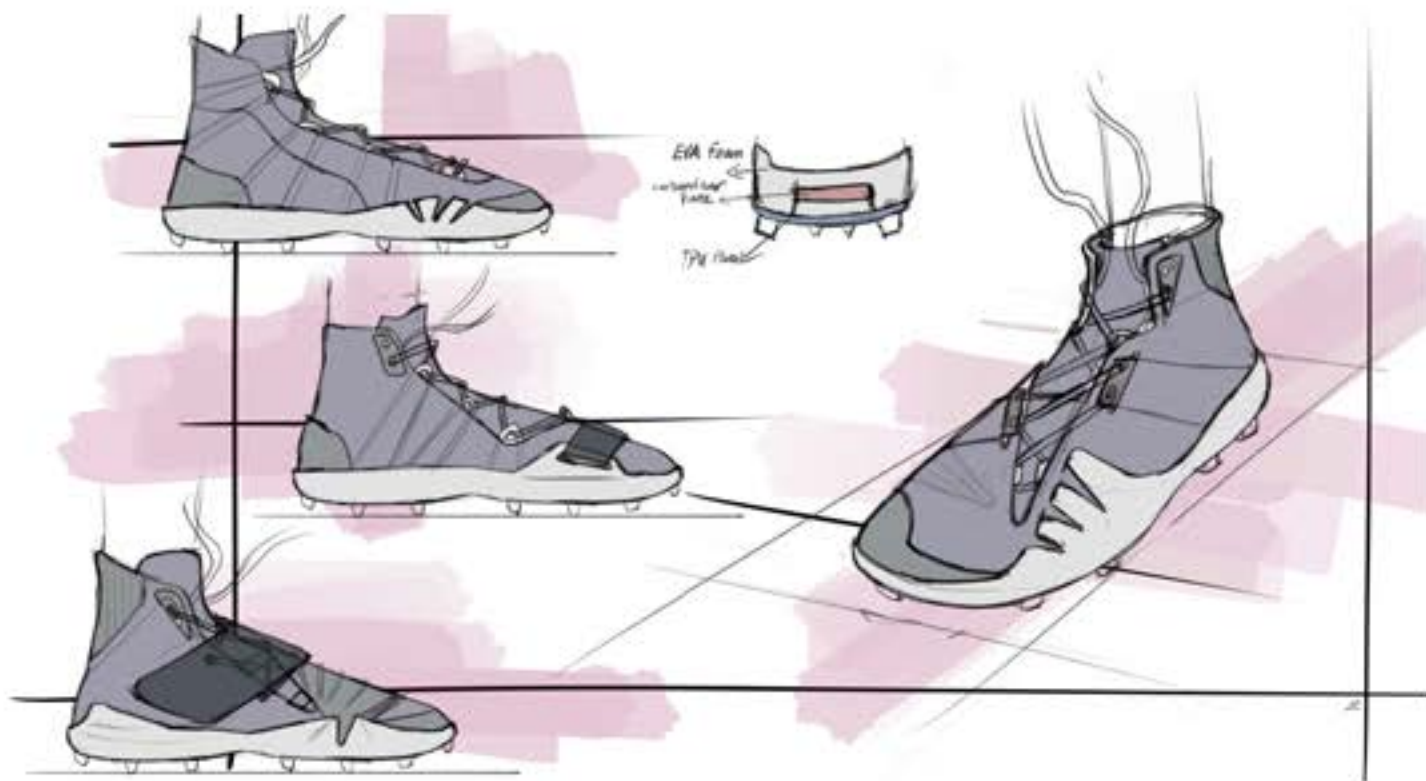
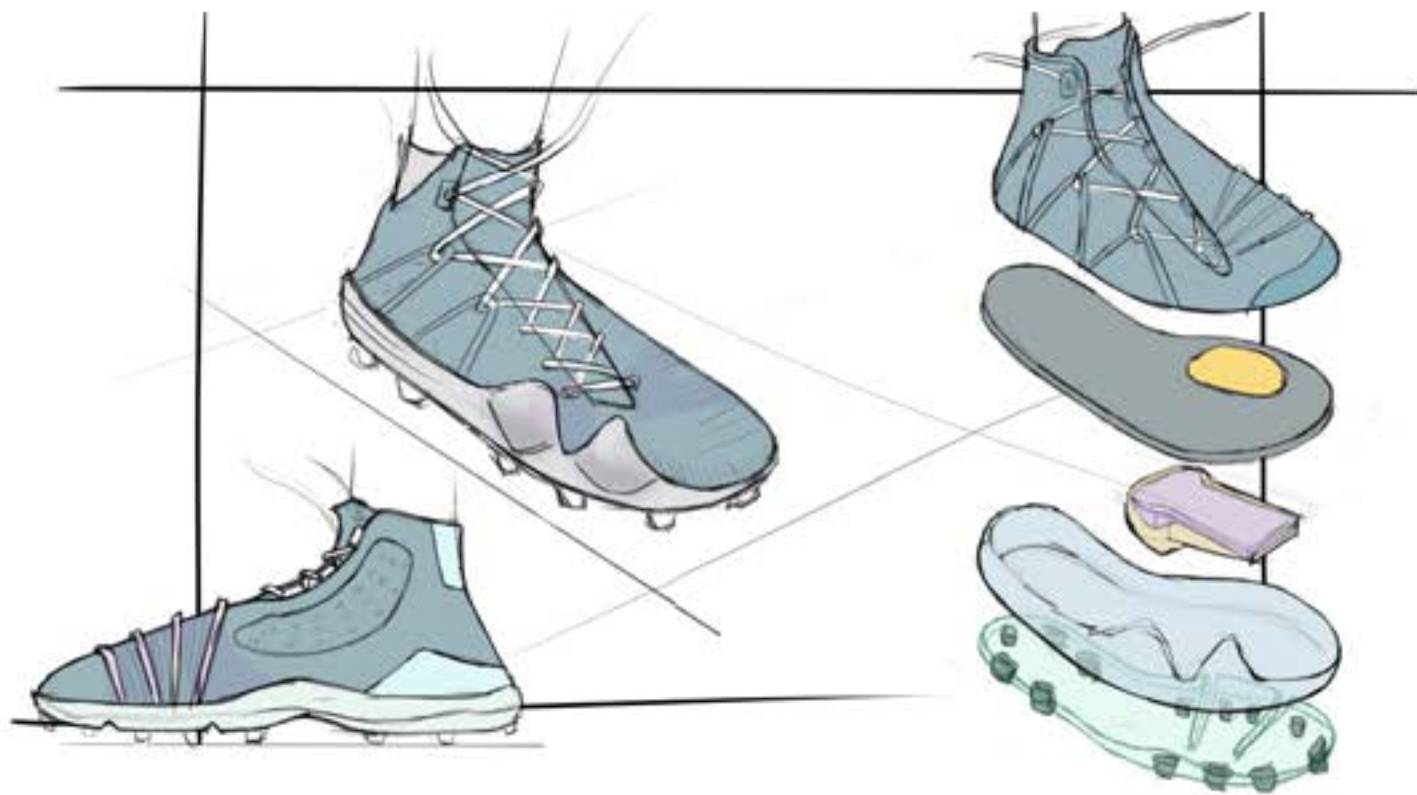




Ideation

Football

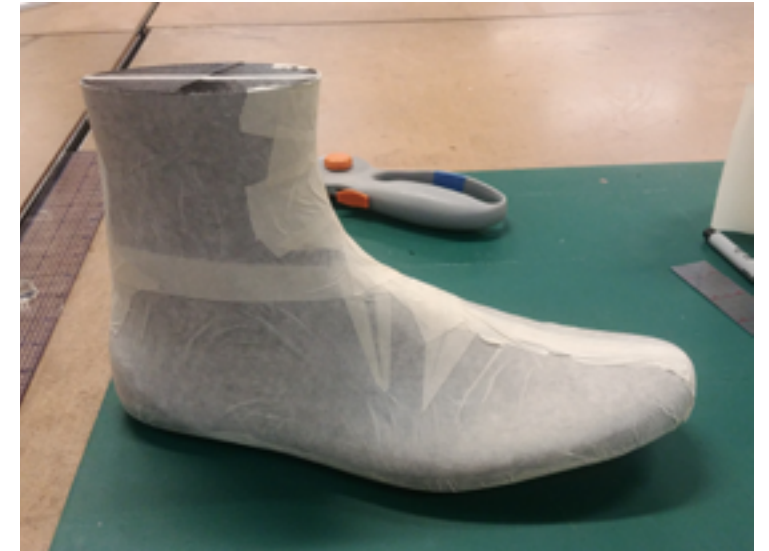




Prototyping

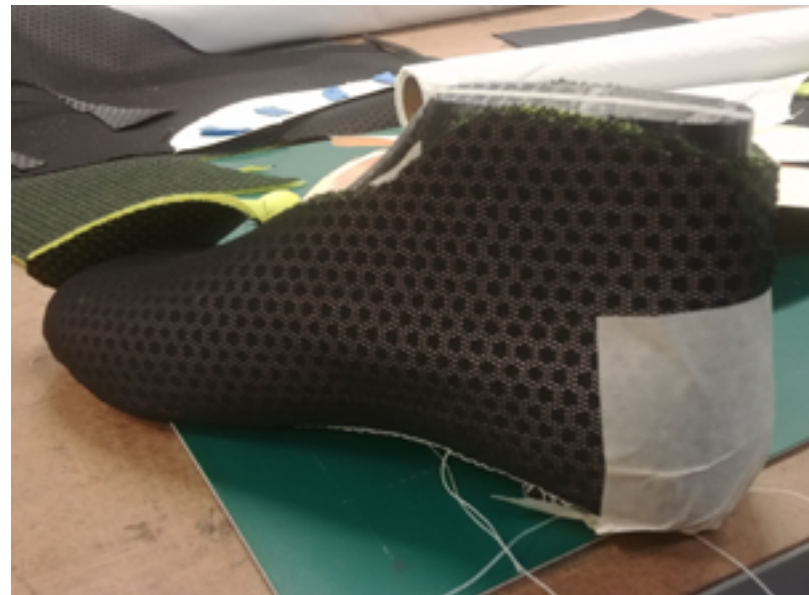
First Round

- Starting with study and modify the toe-spring and heel drop of my customized last
- Using clay model to help explore different form for the cover piece



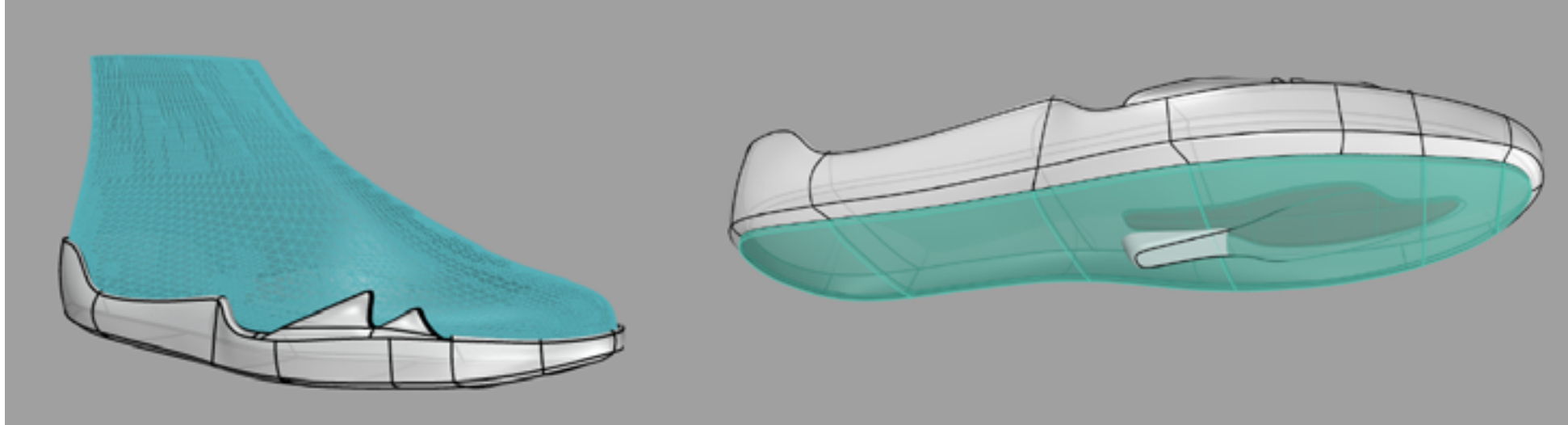
Prototyping

Continuing Upper Prototyping



Prototyping

CAD & 3D



Prototyping

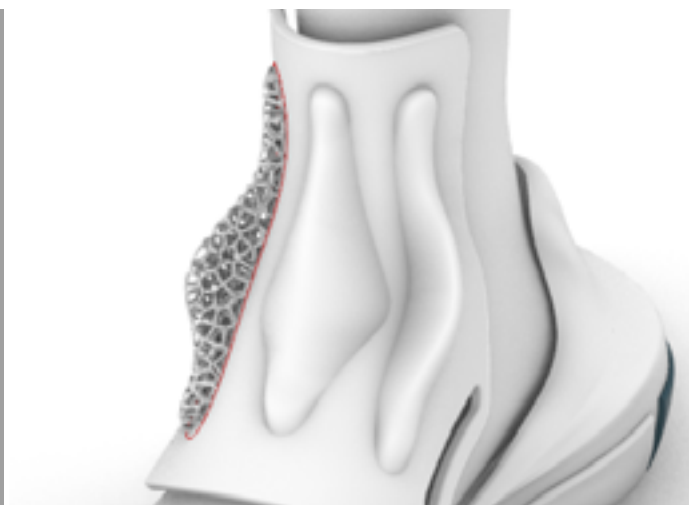
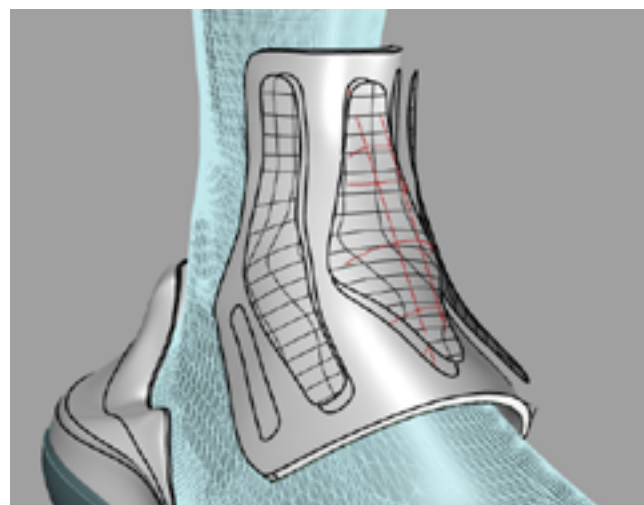
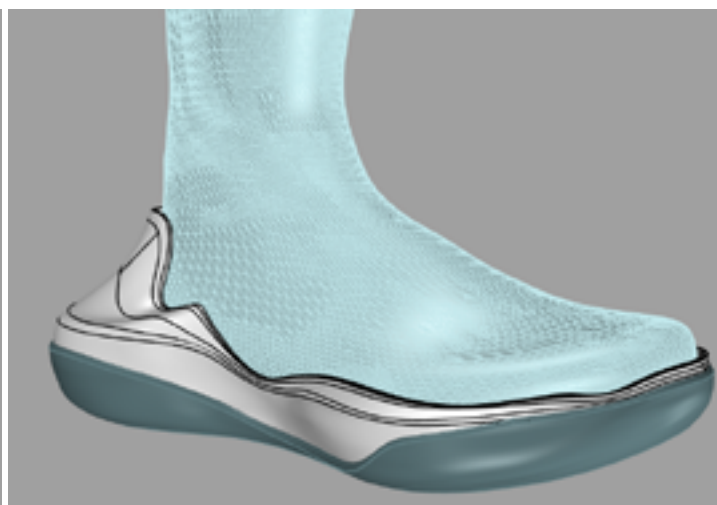
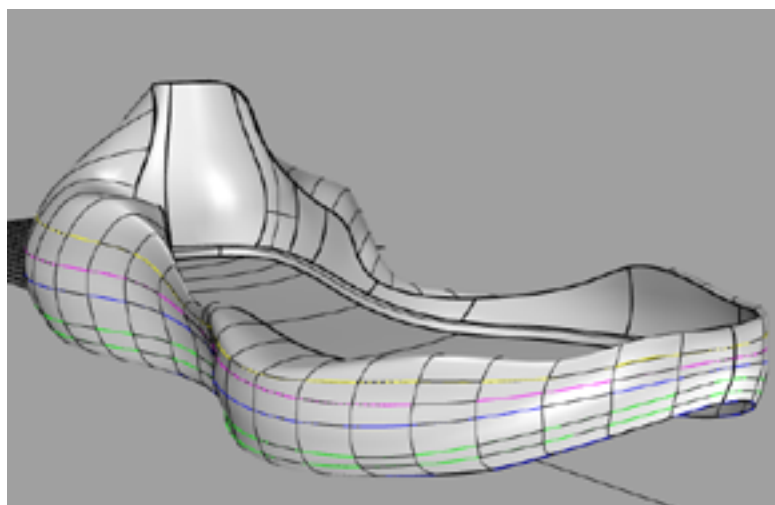
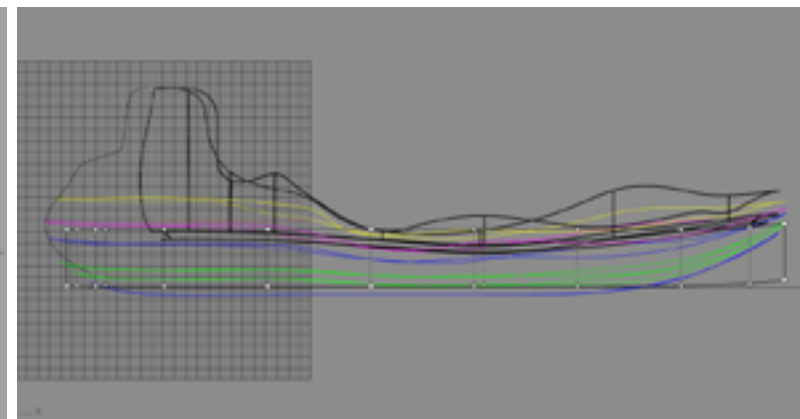
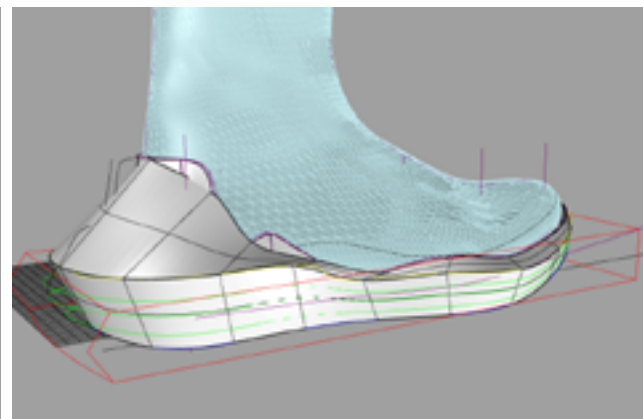
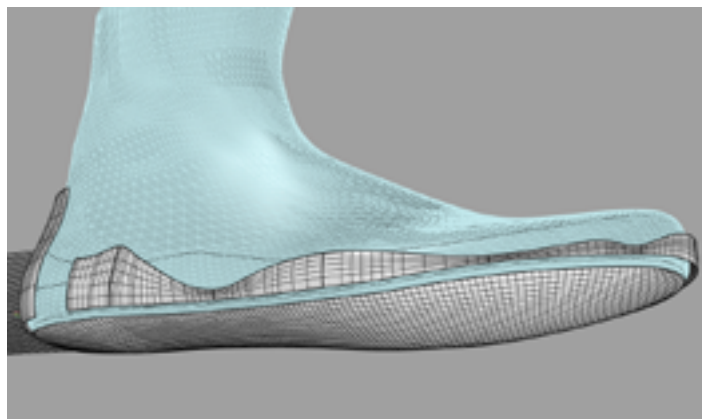
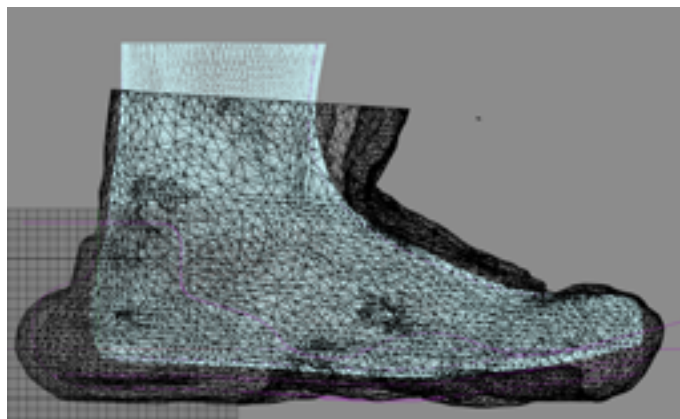
Second Round

Refine and Finalize the Upper Design



Prototyping

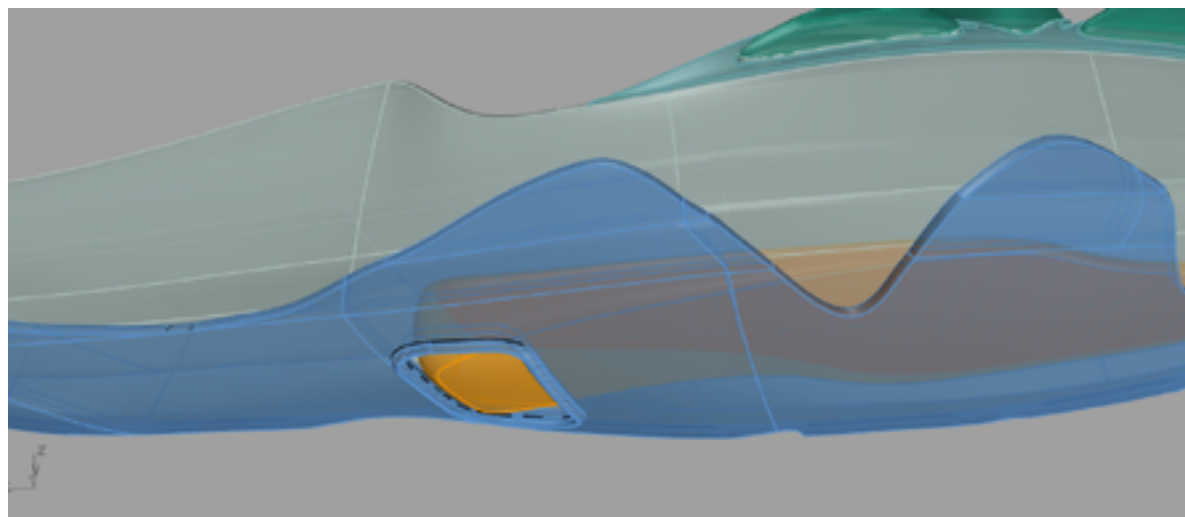
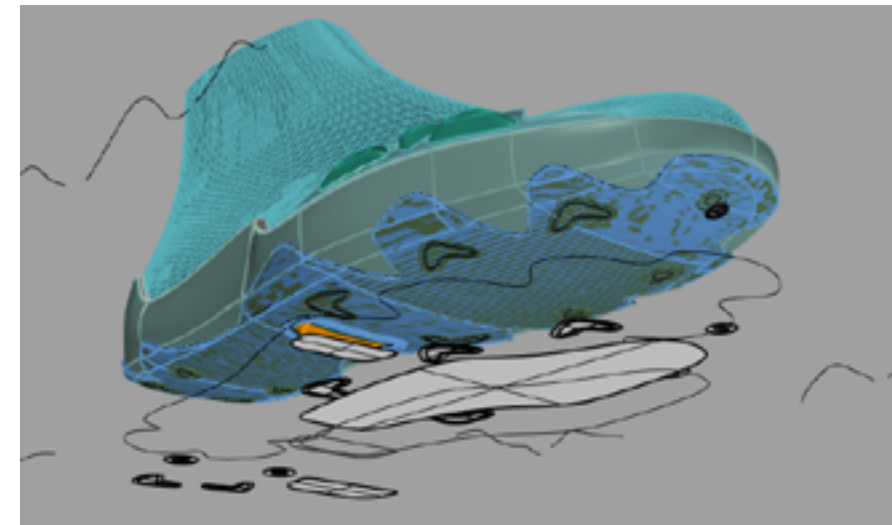
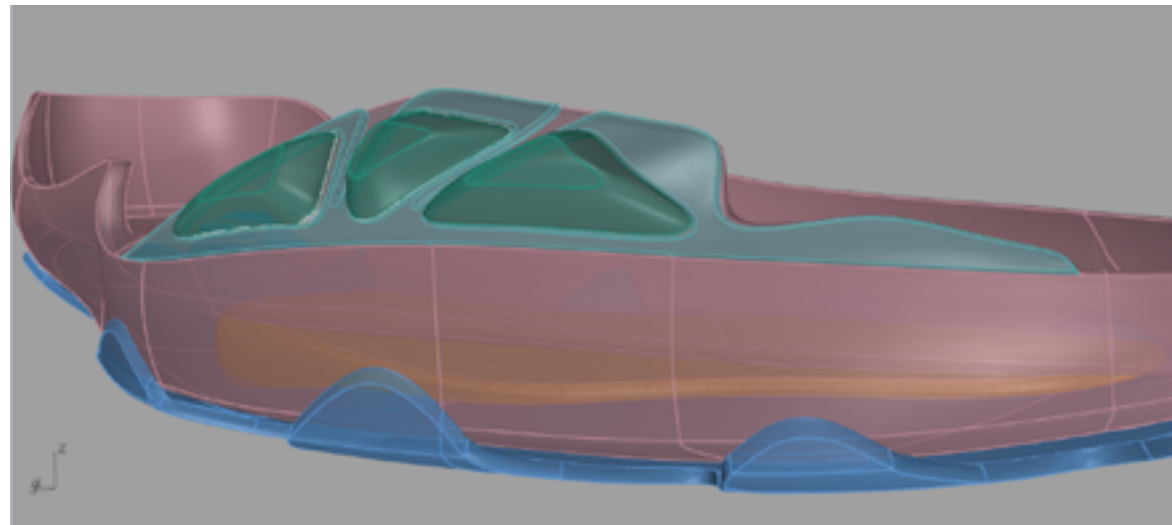
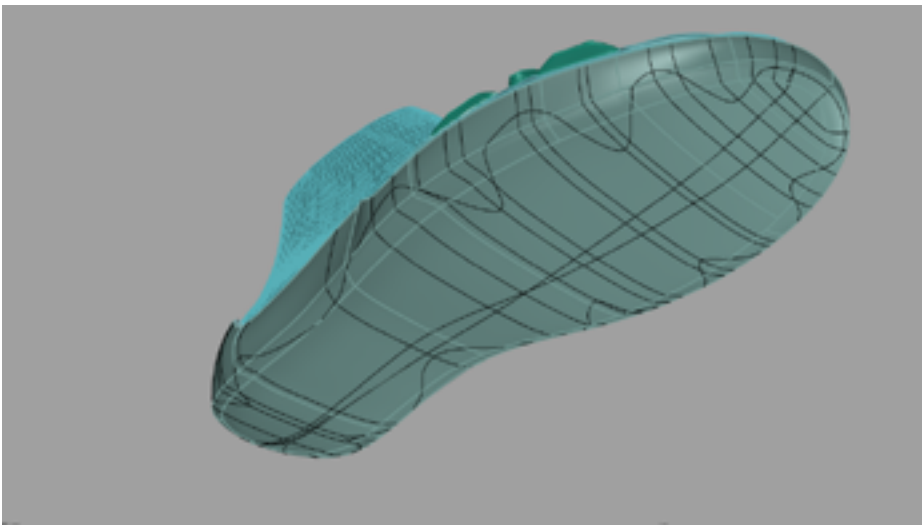
CAD & 3D
Basketball



Prototyping

CAD & 3D

Football



Prototyping

Final Direction





Calendar

	Sun	Mon	Tues	Wed	Thur	Fri	Sat
Week1	Refine and finalize CAD files						
Week2	3D print; Upper making in real material						
Week3	Casting; Upper making						
Week4	Casting; Upper making						
Week5	Validation; Collectng data						
Week6	Revise and finalize the prototypies based on feedback						
Week7	Model the two uppers in 3D; Render the shoes with different colorways and differnet material; Create a short animation video to introduce the features of the two shoes; and showcase the design in different angles						
Week8							
Week9	Photoghaphy of the final product						
Week 10	Preparing for Presentation, get everything ready				Final		

RESURGENCE

Post-injury Recovery Training Football & Basketball Footwear

Capstone Project

Yu Zou

University of Oregon

Sports Product Design

For my capstone project, I plan to design two pairs of recovery/re-injury prevention training shoes for two different sports. The training shoes will be designed for dealing with different foot/ankle injuries that are common to professional athletes. These shoes are intended for professional or collegiate athletes to wear when they are training to get back to the game after a major injury, or when training in the game season while suffering from chronic foot/ankle problems. My choices of the injuries and sports are: 1. A pair of basketball shoes for athletes who are recovering from ruptured Achilles tendon/ experiencing chronic Achilles tendonitis; 2. A pair of football cleats for athletes with turf toe issues (return from surgery/chronic pain).

I will be discussing the details of each topic separately below.

Project 1: Basketball Training Shoes for Athletes Who had Achilles Injuries

Why this topic?

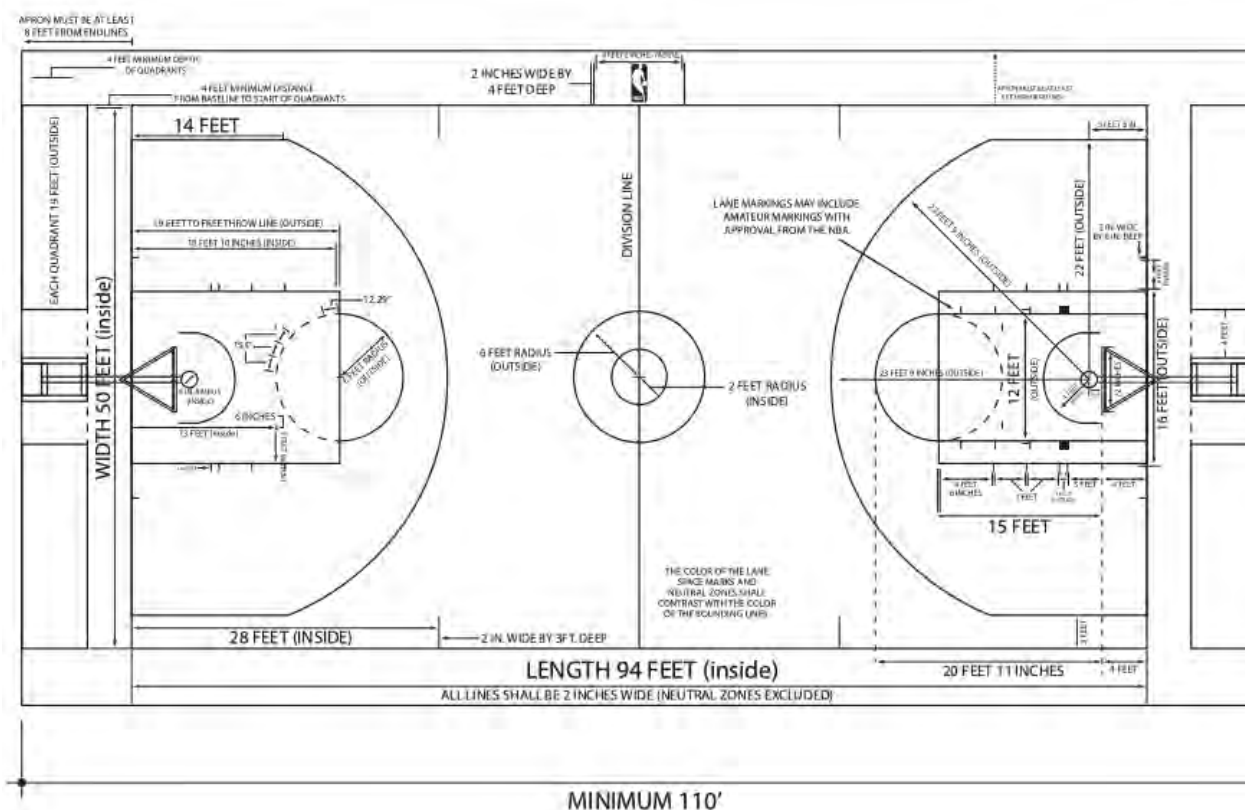
Injuries on Achilles is considered as one of the most likely career-ending impairments for professional basketball players. The recovery time ranges from 6 months to a year. According to a 2013 medical study that investigated cases since 1988, 7 of 18 players who experienced Achilles tendon rupture were unable to return to the NBA. And for those who were lucky enough to make a comeback, none of them could perform at the same level as before their injuries (Amin, et al., 2013). Even suffering from the less severe Achilles tendinopathy, the players could still only perform at a significantly decreased level (Amin, et al., 2016).

Knowing the impact of Achilles injuries never stopped the athletes from training for the return. Through time, with more advanced surgical and training methods have been developed,

we are hoping that players will be able to make full recovery from Achilles injuries in the future. I'm hoping the introduction of my training shoes can be part of the reasons that make the injury less scary. My training shoes are targeting professional athletes who are in the light training period of recovery, meaning the time when they can put weight on their injured side and do low intensity activities but still haven't restored full strength or range of motion.

Playing field/ Environment

A standard NBA basketball court is 94 feet long and 50 feet wide. The court is divided into two halves, and consists a three-point line, free throw lane, the paint area, the restricted area on each side. The lines are all 2 inches wide (Rule,2019).



Sports positions

Traditionally there are five distinctive positions for the five players on each team: 1. Point guard, who is usually the shortest on the team but with the best ball-handling skills. A point guard is expected to direct plays. 2. Shooting guard, who is usually the second shortest player on the team and the best shooter and potentially scorer. A shooting guard is expected to have good dribbling skills and able to contribute points from everywhere 3. Small forward, the shorter forward, who is supposed to be the most versatile player on the team. A small forward should be tall and strong enough to play on the inside as well as agile enough to play on the outside. 4. Power Forward, who is usually the second tallest player on the team. A power forward is expected to score inside as well as hit some midrange shooters. They also usually hold important roles in defensive play. 5. Center, who is often the tallest and strongest person on the team and is positioned nearest to the basket. A center is usually expected to control rebounds on both offensive and defensive side. Their scoring range are usually close to the basket and a lot of them could come from offensive rebounds.

However, as the game has been developing through the years the differences between each position have been blurred. We now see all types of players creating their own playing style for different positions and switching between positions smoothly.

Rules

A successful field goal attempt from the area inside the three-point line shall count two points. A successful field goal attempt from the area outside of the three-point line shall count three points. A successful free throw attempt counts one point. An NBA game has four

regulation play periods. Each period will be twelve minutes long. The team that scores the most points wins the game (Rule,2019).

A regular NBA season consists 82 games (41 home, 41 away). The top 8 teams on each conference can enter Playoffs games and compete for the championship.

Athletes data, market size

During the regular season, each team can have up to fifteen players on the roster, plus two spots for players who are under “two-way contracts”. This means the NBA has a maximum of 450 players. During the offseason, each team can carry up to twenty players and the NBA may have as many as 600 players.

Physiological/ biomechanical needs

The Achilles tendon is a strong fibrous cord that connects the back of the calf muscles to the heel bone(calcaneus). It is essential to many movements including standing, walking, running, and jumping. In basketball, players have to constantly put their Achilles tendon in action in order to run, cut, jump or land. The tendon helps to absorb impact and propels athletes' forwards. Even though it is the strongest and the largest tendon in the human body, the Achilles tendon is also prone to injury due to the high tension placed on it and the limited blood supply (Hoffman, 2019).

There are many levels of Achilles injury, the common ones are: Achilles tendon tear (can be tiny or large, can happen suddenly or gradually overtime), Achilles tendon rupture (a complete rupture, usually happens suddenly during activity, the most severe level of Achilles injury, often requires surgery and/or long-term immobilization of the ankle), and Achilles

tendinitis (usually caused by overuse of the tendon which gradually inflame the end of the Achilles tendon) (Hoffman, 2019).

Current/competitor product research (products, price points, features and benefits)

Overall: Currently in NBA, 63% of players choose to wear Nike (72% if include Jordan Brand), 16% of the players wear adidas and that leaves just 12% for other brands (Under Armour, Puma, Li-Ning, etc) (Gallinger, 2019).

Individual product research: Since I do not have any access to the actual game used shoes provided for the NBA player, the research will be based on the products that are sold in consumer market, with the understanding that player edition shoes usually use upgraded technology (ie. Full length carbon fiber plate or an extra piece of zoom air).

A decades ago, people might still talk about what shoe is for what position, but today there really isn't a boundary. Athletes simply choose the shoes that fit their specific needs.

Nike & Jordan brand (based on nike.com):

Kobe AD NXT

Retail Price: \$200



The Kobe AD NXT offers a close, consistent fit with just one pull thanks to Nike's FastFit technology. The midsole is made with full-length Nike React foam plus a layer of Cushlon foam. An internal 4-way mesh material locks the foot in and conforms to the shape of the foot to provide a custom fit. The rubber outsole with multidirectional tread grants traction on demand.



Air Jordan XXXIV

Retail Price: \$180

The Air Jordan XXXIV has an unconventional midsole which includes an eclipse plate made from molded TPU.

The hollowed part allows consumer to see the Zoom Air cushioning unit in the heel as well as reduce the overall weight of the shoe. Another Zoom Air unit is embedded under the forefoot. The outsole has the traditional herringbone pattern which provides multidirectional traction. The upper is made with mix of textile and translucent materials for lightweight, breathability and comfortable fit.



Lebron 17

Retail Price: \$200

The Lebron 17 features a lightweight mix of knit and heat-molded yarns that are durable and supportive (KnitPosite). For cushioning, it utilized the largest heel Max Air unit, which is designed specifically for Lebron, and a maximum volume Zoom Air unit at the forefoot. It also has a plastic wrap heel counter to lock the foot in for stability.



Nike Zoom KD12

Retail Price: \$150

The Nike Zoom KD12 features a full-length Zoom Air cushioning unit that is stitched directly to the upper, replacing a traditional Strobel board for a faster responsiveness. An additional Zoom Air unit is

added under the heel for the extra bounce on the court. The upper utilized 4-way directional Flywire cables that provide targeted stability and on-the-fly lockdown. The midsole is also perforated to keep the foam flexible while reducing overall weight of the shoe.



Kyrie 6

Retail Price: \$130

The Kyrie 6 is equipped with a Zoom Turbo unit under the forefoot. The adjustable strap over the laces helps to keep the foot stable. The padded collar and heel

counter lock in the ankle and keep it aligned with the foot to generate more energy when making hard cuts. The rubber outsole contains a multi-angle blade pattern which provide gripping in all direction. The outsole also extends up to the sidewall, which provides traction when the foot pushes on its edge in certain moves.



Zoom Freak 1

Retail Price: \$120

The Zoom Freak 1 has two units of Zoom Air stacked on top of each other in the heel, providing extra cushioning and response. It also has internal bands that

lockdown the forefoot when laces up. The rubber outsole contains geometric patterns for traction, and one clip also extends to the upper for lateral support.

Adidas (based on adidas.com):

Harden Vol. 4 shoes



Retail Price: \$130

The Harden Vol. 4 features ultra-light and responsive midsole cushioning—Lightstrike. The textile upper has a midfoot band to provide lockdown and stability. The generative outsole traction is designed specifically for Harden, based on his unique movements on court.



Dame 6 shoes

Retail Price: \$110

The Dame 6 utilized the ultra-light Lightstrike cushioning in its midsole to provide responsive shock absorption. It also has a web-like lacing system to keep the foot in lockdown. The herringbone rubber outsole provides traction in all direction.

D.O.N. Issue #1 shoes

Retail Price: \$100



The D.O.N. Issue #1 is equipped with flexible Bounce midsole cushioning. It also has a propulsion clip to provide lateral stability and rubber outsole with multidirectional herringbone-pattern traction.

Under Armour (based on underarmour.com):



Curry 7

Retail Price: \$140

The Curry 7 features the UA HOVR technology which provides ultimate energy return, paired with Micro G cushioning to make the first step more explosive. The upper uses mixed materials on different location to provide the best comfort, mobility and support. The herringbone traction pattern is used on the rubber outsole to provide maximum floor control and grip.

Anatomy of typical state of the art product



A typical basketball shoe consists an upper, an insole, a midsole and an outsole. The upper is usually lined with soft fabric on the inside and is strobelled onto a Strobel board then glued to the midsole. The cushioning technologies are usually embedded in the midsole which is also the most important part of a basketball shoe. Most basketball shoes today will have a dual density midsole for shock absorption and fast energy return. The outsole is usually made with soft rubber for better gripping on the wooden floor. The midsole and outsole are usually glued together, but in some cases the outsole can be molded on to the midsole through double shot injection molding.

State of the art material & manufacturing

Upper: Currently 4D Knitting/woven is the most popular technology among different companies. Each brand has developed their own patented computer numerical controlled knitting

technology and has continued to innovate on the materials and knitting patterns. 4D knitting allows the upper to have different texture, thickness, and material at different location without having stitch line. It also reduces waste by only produce the part needed. Yarns used in 4d knitting are mostly nylon and polyester. Companies are also constantly integrating new materials like heat-molded yarns (used in the KnitPosite) into the construction for better performance.

Midsole: Most midsoles are made of foam, which are proprietary polymers made by injection molding. Adidas' Boost technology utilized a special treated TPU that is developed by German chemical manufacture BASF. Nike's React technology is completely developed inhouse and the proprietary technology is essentially a new synthetic rubber. Currently most basketball shoes only use different density foam for cushioning, however, Nike has continued to develop its Air cushioning technology. The newer Max Air and Zoom Air are bigger in volume and more responsive and durable.

Outsole: Most outsoles are soft rubber made by die-cut from large sheets of rubber then heat molded to desired shape. Some companies will add proprietary compound in the rubber mixture to make it more durable & grippy.

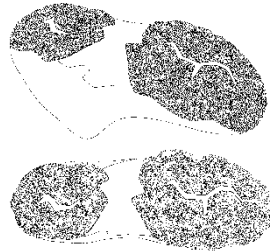
Utility Patent

US20190350310A1 Footwear having auxetic structures with controlled properties

“An article of footwear includes a sole incorporating a plurality of apertures extending from an upper surface. The article of footwear further includes a strobel that may be placed along the auxetic structure of the sole. The strobel may restrict the flexure of the sole in particular locations to varying degrees.” (Langvin,2016).

USD707934S1 Shoe Outsole

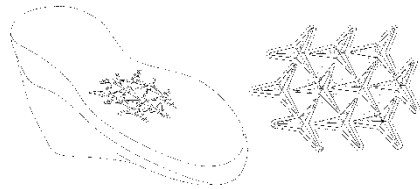
Shoe Outsole Design



(Petrie,2014)

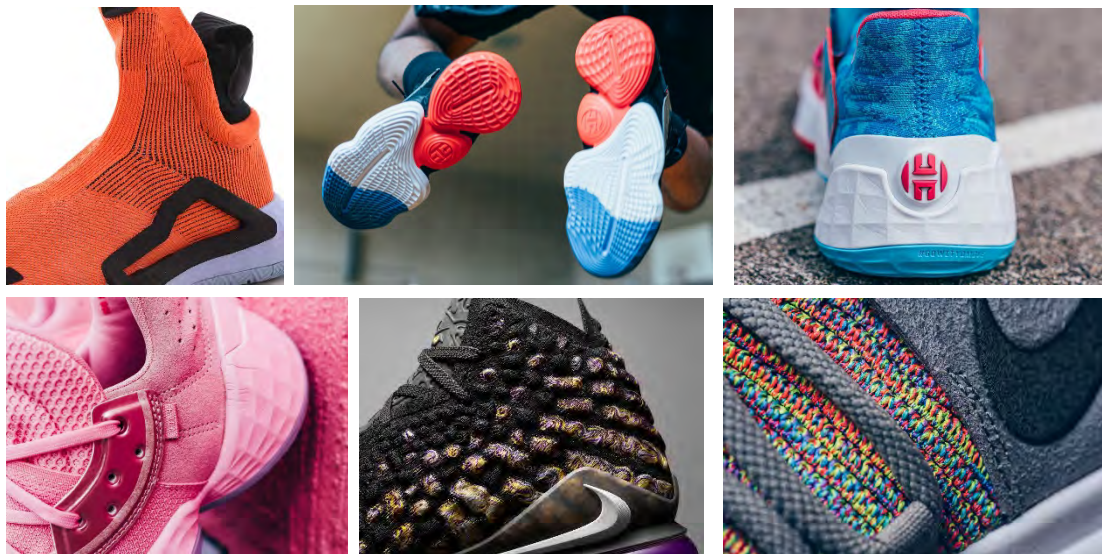
USD716027S1 Shoe Outsole

Shoe Outsole Design



(Kirschner,2014)

Graphic, logo and color application on current product space



More and more of the graphics on the upper are patterns created by 4D knitting, utilizing different color & material yarns. The graphic and logo are made from generally minimalistic

geometries. There is a trend to use computer generative patterns on the sidewall and outsole design. Even though this is the most primitive application of generative design, it does make the communication and revising process much easier when designing in a team. The color trend in basketball shoes have not changed much through the years. Most styles in the market will have one safest colorway that shows in most promotions. This colorway usually has a neutral base color with some bright accent color that is relevant to the story behind the design or the team that the player is currently playing for. Other than the main colorway, there will usually be a few colorways inspired by the player's personal stories or favorite tv show, or collaboration with other brands. These colorways can be very bold and fresh, which is commonly preferred by basketball players. The 4D knitting technology allows more colored threads to be shown on one upper which encouraged the trend of multi-color knit pattern. Another trend is to combine different materials to give different locations of the upper different function as well as create a layered look.

SWOT analysis

Strengths: The flagship products always have access to the newest technology a company has and are designed by the best design team. The current products all could easily provide sufficient protection, support, cushioning and comfort for the players.

Weaknesses: The design of basketball shoes seem to fall into a simple formula: springy responsive midsole cushioning + comfort & supportive upper + lateral & heel support + outsole with traction patterns. The most exciting part of a new basketball shoe is always the new technology that is used on it. Designers are getting less creative with other methods to solve problem/ innovate.

Opportunities: The current products in the market are all designed for the high-performance requirements when playing a game. None of the shoes targets the players' need for training/recovery.

Threats: The big brands have the resources to quickly develop new products that target the same market, which is hard to compete with.

Project 2: Football Training Cleats for Players with Turf Toe Problems

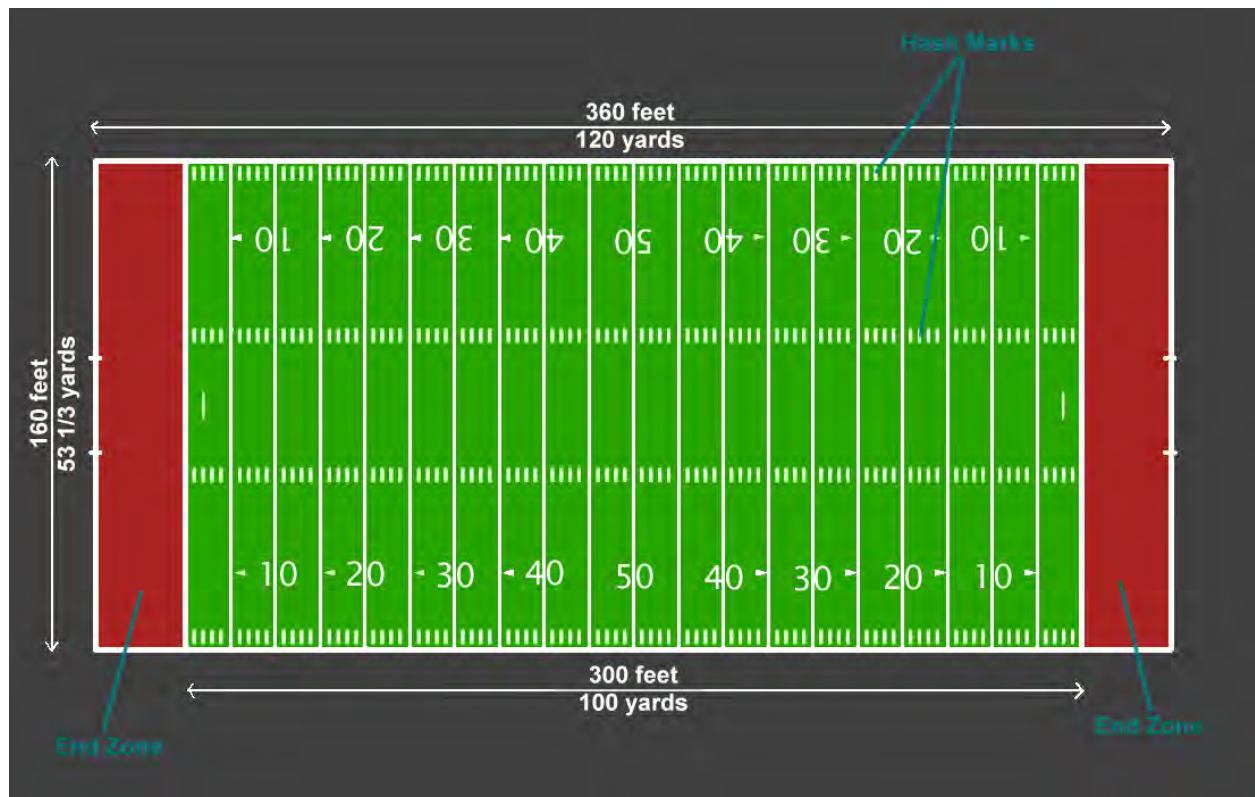
Why this topic?

“Turf toe” is the common term used to describe a hyperextension injury to the first MTP joint with varying degrees of injury to the plantar capsule, plantar musculature, and sesamoid complex (Gamradt & Brophy, 2009). Turf toe has been one of the most common injuries in football since the introduction of the artificial turf. The reported injury rate in professional football players has been as high as 45% (Poppe, Reinhardt, Tarakemeh, Vopat, & Mulcahey, 2019). Many studies have been done about turf toe since 1976, but there is still not a conclusion on how to avoid the injury from happening. Many studies have shown that once an athlete suffered turf toe injury, their MTP joints persistently lose range of motion.

Turf toe is usually not a severe injury and can be recovered just by resting and physical therapy, the recovery time can be from a couple of days to a few weeks depends on the degree of injury. However, in some rare cases the injury needs to be treated with surgery and can be career-ending (Poppe, Reinhardt, Tarakemeh, Vopat, & Mulcahey, 2019).

Because of the commonality and the lingering nature of the injury, I want to design a pair of training cleats for professional football players who are bothered by turf toe. The cleats will be focusing on protection and avoiding putting more stress on the MTP joint.

Playing field/Environment



According to official NFL playing rules: The game shall be played upon a rectangular field, 360 feet in length and 160 feet in width. The lines at each end of the field are termed End Lines. Those on each side are termed Sidelines. Goal Lines shall be established in the field 10 yards from and parallel to each end line. The area bounded by goal lines and sidelines is known as the Field of Play. The areas bounded by goal lines, end lines, and sidelines are known as the End Zones. The surface of the entire Field of Play must be a League-approved shade of green (NFL,2011). NFL fields have a 6' line along the side lines that designate the closest non-players can be to the field and the goal posts are 10 feet high and 18 feet, 6 inches wide.

Sports positions

An NFL team usually have 3 sub-teams: defensive, offensive, and special teams. The defensive position includes: the defensive line, the linebackers and the defensive backfield. The goal for the defensive unit is to stop the opposing team's offensive play by either tackling or taking the ball away so that the other team couldn't score by touch down or kicking a field goal.

The offensive position includes: the offensive line, the offensive backfield, the tight ends and wide receivers. The goal for the offensive unit is to take control of the football and move it downfield and eventually score a touchdown or kick a field goal.

The special teams are the group of players that specialized in kicking plays which includes backup players, starters and specialists. ("Football Positions Guide: Offensive, Defensive, and Special Teams", 2019)

Rules

An NFL game is 60 minutes long, divided into four periods of 15 minutes each. The team with the greater number of points at the end of the game wins. There are four ways to score: a touchdown is worth 6 points, a field goal is 3 points, a safety is 2 points and for try after touchdown is 1 point after a field goal of safety and 2 points after a touchdown.

Before the game starts, the referee tosses the coin to decide which team captain can choose one of the two privileges, and the loser is given the other. The two privileges are: 1. The opportunity to receive the kickoff, or to kick off; or 2. The choice of goal his team will defend.

Each team should have 11 players on the field. Players' number should follow the rules which specified the range of numbers for each position. ("2019 NFL Rulebook")

Athletes data, market size

Each NFL team is allowed to have a roster of 53 players, in which 46 players can dress out for the actual game. The NFL currently have 32 teams, making the totally number of players at about 1696.

Physiological/ biomechanical needs

The name “turf toe” was first used by Bowers and Martin in their 1976 paper, in which they discovered the sprain of the plantar capsule-ligament complex of the great toe metatarsophalangeal joint is caused by the combination of a relatively flexible shoe with a relatively hard artificial playing surface (Bowers & Martin, 1976).



In football the injury often happens when the foot is fixed on the ground, with the heel elevated, and a player falls on the back of the foot. The turf toe injury is classified to 3 grades. Grade 1 is the least severe, the plantar structure will swell but the foot usually can get back to normal after resting for a few days. Grade 2 injury has minor tears on the plantar structure, the athletes may need walking boot/crutches for two weeks. When they return to play, they may need to tape their MTP joint to help with stabilization. Grade 3 is the most severe level; the plantar structure is completely ruptured and in most of the cases surgery is needed. When the athlete returns to play, he will also need to tape their foot (McCormick & Anderson, 2010).

Current/competitor product research (products, price points, features and benefits)

NFL regulation allows players to wear the cleats that are from the three league approved footwear brands: Nike, adidas, and Under Armour. Like the shoes provided for NBA players, each brand will provide NFL players shoes with better configurations. Many teams in the NFL

have team-wide contract with brands, and a lot of players also have individual contracts with brands. The equipment manager of each team is responsible for providing the right type of shoe for each game, considering the weather and the type of field (natural grass or Astroturf). An NFL team consumes about 2,500 pairs of shoes each season (Brain, 2000). Since I do not have access to the player edition cleats, the research will be based on products that are sold in market.

Nike (based on Nike.com):



Nike Alpha Menace Turf Low

Retail Price: \$100

The Nike Alpha Menace Turf Low is made for practice. It features adaptive rubber pegs on the center of the outsole for traction. The forefoot hook and loop closure strap helps to secure the fit. The lacing system integrate Flywire cable for an adaptive, supportive fit.



Nike Vapor Untouchable 3 Elite

Retail Price: \$200

The Nike Vapor Untouchable 3 Elite features a carbon fiber plate with innovative stud geometry. The Flyknit upper integrates Flywire cables to provide lightweight lockdown.



Nike Vapor Untouchable 3 Pro

Retail Price: \$120

The Nike Vapor Untouchable 3 Pro features a carbon fiber plate at the forefoot to provide more power for takeoff. The knit cuff adds comfort while locking the foot in. The Flywire in the midfoot provides adaptive support.



Nike Vapor Untouchable 3 Speed

Retail Price: \$95

The Vapor Untouchable 3 Speed features a one-piece seamless upper to lockdown the foot. The low-cut silhouette promotes natural movement around the ankle



Nike Force Savage Elite 2

Retail Price: \$140

The Nike Force Savage Elite 2 feature 3 hooks-and-loop straps for ultimate lockdown and support. The Fastflex plate promotes natural motion. The tongue wraps from the lateral side of the shoe to the arch to eliminate seam at the top of the foot. It also has an internal heel cup to secure the foot.

Under Armour (based on underarmour.com):



UA Spotlight MC

Retail Price: \$110

The UA Spotlight MC features a woven upper with TPU coated yarns for comfort and zonal support. It has an ultra-light weight speed plate that combines BZM and TPU for stability. The mixture of bladed & conical studs are strategically placed to provide better support for athletes' movements. The SuperFoam insole is used to provide shock absorption and comfort.



UA Highlight MC LE

Retail Price: \$140

The UA Highlight MC LE features a synthetic upper with strategically zoned areas for breathability and support. The molded 4D Foam footbed conforms to the shape of the feet for better support, gripping and comfort. The UA Scatter Traction cleat plates also supports powerful movements in every direction.



UA C1N MC

Retail Price: \$160

The UA C1N MC features a carbon fiber cleat plate that provides lightweight and responsive traction. It also utilized the molded 4D Foam footbed to provide a customized comfort and support. The innovative lacing system ensures the cleats stay locked in during cuts.

Adidas (based on adidas.com):



FREAK ULTRA CLEATS

Retail Price: \$180

The adidas Freak Ultra Cleats features a boost midsole for responsive shock absorption. The Primeknit upper provides support without sacrificing comfort.

Anatomy of typical state of the art product



A typical football cleats consists a cleated plate, an insole and an upper. Most of the cleats do not have a midsole. And for the ones do have a midsole, the midsole is usually really thin. The upper is

sewed onto a strobel board then glued to the plate. The toe box and heel counter of the upper are usually reinforced on the inside/outside for better support and lockdown.

State of the art materials & manufacturing

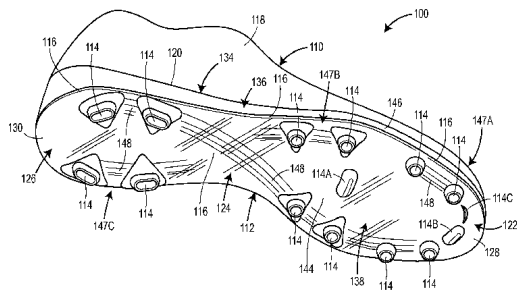
The most important part of a football cleats is the plate. It is usually a TPU plate made from injection molding. The higher end cleats will have carbon fiber plate and fiber glass integrated to the TPU plate to provide a more explosive push-off. The studs are usually also made with injection molded TPU, but it can also be made of rubber or metal.

The upper is often made of synthetic materials that are die cut from a large piece of material. However, in recent years, it is more popular to use a 4D knit upper that is CNC weaved together and reinforcing key areas with heat molded TPU for comfort and zonal support.

The insole is usually the only part that provides cushioning in a football cleats since most of the football cleats do not have a midsole. The insole is usually die cut from a large sheet of foam.

Very few products on the market have a midsole. The midsole is usually made of foam, which is made from polymers through injection molding.

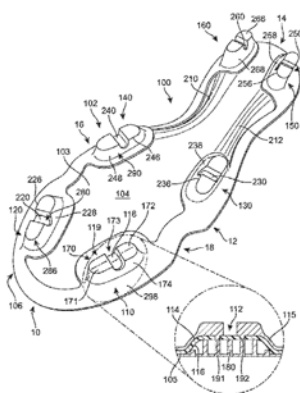
Utility patent



US20190357631A1

Sole structure with integrated cleat member and methods of making

(Gerber, 2011)



US20190328081A1

Article of footwear with soil-shedding performance

(Walter et al., 2016)

Graphic, logo and color application on current product space



Majority of the colorways for football cleats on the market uses one neutral base color like black, white or grey, and add some accent color that is relevant to the team/ on trend. The upper usually don't have any printed graphic other than patterns and texture created by the materials. Recent years, more and more generative design is used on creating the texture on the plate. And sometimes iridescent materials are used on the plate to create a futuristic look.

However, for athletes who hold individual contracts with brand, like Odell Beckham Jr., can get customized cleats based on what he wants. He has been rocking different customized cleats almost every week this season, and the graphic inspirations range from classic sneakers' colorway to popular movie character.

SWOT Analysis

Strengths: The elite level football cleats are all equipped with the most advanced technology and materials. Many resources are provided to the design team to innovate. And they have access to consult with professionals in other field to help them actualize their design.

Weaknesses: The focus of design has been similar and less exciting. New technology and material have dictated the problem-solving methods.

Opportunities: Most of the cleats are performance driven, overlooked players needs in training and recovery. There isn't a football cleats in the market that are designed for athletes with turf toe problems.

Threats: The big brands have the resources to quickly take over a new market space.

Strength Alignment

Zou has been interested in sports footwear since she was 12 and her knowledge about sneakers extends from the technology to their cultural significance. Zou has shown significant improvement on her 3D skills in the past year, which is essential to design and prototype footwear, especially for midsole and outsole. Generative design has become more and more standard in footwear design industry especially when creating new patterns and structures. Zou's ability to use almost all the popular software that are used in the industry allows her to innovate on the same platform as the big companies. Because Zou has shown her ability to learn new skills quickly, she is also confident to grasp any new software she must learn during the creation process of her capstone.

Zou is also good at working with her hands, which is another plus for prototyping. She will be able to pattern, sew, and construct mold quickly, which can be great help for ideation and testing. Zou have adequate amount of training in biology, chemistry, physics, math, and statistics which allows her to understand academic papers in differently fields. Her scientific background allows Zou to comprehend medical /biomechanics /physiology papers that are needed for the research of this project, which is essential to create solution that can solve the problem.

Zou wants to work in the footwear industry after she graduates, and this project can allow her to show her skills and abilities on multiple aspects related to footwear design.

Field Work

After researching on academic studies and human anatomy related to the two injuries, I wanted to learn more feedbacks from athletes and professionals in the fields to get a better sense of what are needed for the new design. I was especially interested in sports specific recovery protocols and how certain problems are addressed in current performance driven product. Human foot is extremely complicated and there are wide range of factors to consider while designing a shoe. I was amazed but also a little overwhelmed by the amount of information I gained during research process. Therefore, I hoped to get suggestions from biomechanists so that I can figure out the priorities of the problems I'm trying to solve and ensure that I'm focusing on the most essential needs as well as working on the right path.

I was lucky enough to get access to the Adidas US campus and visited two sports scientists at their Athletes Services department. During my visit, I first met with Eric Sterner, who is the senior manager at the department and my main contact for this tour. Eric has a

background in human physiology and biomechanics. His main role at adidas is working directly with athletes (mostly sponsored professionals) who participate in cleated sports (e.g. football & baseball). Eric showed me the current solution they provided for athletes who have turf toe problems. The most common way to do it is to make the shoe stiffer so that their feet won't bend as much. Eric told me that a lot of the modifications they can do are adding plates into existing products. They buy fiberglass sheets in different stiffnesses and waterjet cutting the plates to the shape of the insole. Then they heat up the plate to fit the curvature of the cleats and left it inserted and glued under the insole.

I then asked Eric more detailed questions about what different part of the design he thinks can help with the recovery training process. I asked about the stud placement, size and shape. And Eric believes that the placement doesn't have much influence in the comfort/function since the placement has been tested and developed for years. However, the size and shape of the studs affect the traction a lot which is associated with the force applied to the foot and joints. Typically, round studs are most common, which is good for motion and spin. The triangular/rectangular shaped studs are better for cut and stop. The bigger the studs are, more traction they provided. For my design purpose, I should reduce the traction and allow more slippage to alleviate the pressure on the foot from the more sudden movement/force caused by braking and cutting. Eric also suggested me to consider heel spring & toe spring of the shoe which plays an important role in the comfort of each step, and to keep in mind the chain reactions between each part of the foot.

After talking to Eric, I met with his colleague Justin, who also has a biomechanics background and is mostly working with basketball athletes at adidas. Eric told me that in his opinion the most important thing to consider is comfort. For example, after the surgery the

surgical incision will cause the area around it to be very sensitive and tender, therefore, a less angled and softer heel rake design can help reduce the irritation caused by the shoe. Another example is that since Achilles tendon is essential for shock absorption when walking and running, after the surgery the athletes will need more cushioning at their heels to help reducing the impact on the tendon and therefore lesson the pain caused by the shock. I shared my idea for a motion restriction system idea to Justin, which will involve a strap wrapping around the heel and the middle part of the anterior tibial tendon to limit the range of motion. The system will also include a flexible TPU compartment on top of the tongue and upper to also help avoid the extreme dorsiflexion of the foot. Justin thinks that my idea could work but I should mindful of how the parts interact with the foot and ankle.

Another question that I had was about the heel-toe offset, which is related to the force works on the Achilles tendon. Justin agrees that increase the heel drop can help reduce the stress on the tendon but since the foot is a complication system that involves many muscles, bones, tendons, ligaments, etc., I should be aware of the other effect the design might cause. In the case of raising the heel drop, the Achilles tendon does less work, however, the talus bone is less constrained at the same time and could make ankle sprain easier. Another topic Justin mentioned was toe spring and heel spring as well. Like what Eric told me, Justin thinks a smooth transition for every contact with the ground is important to provide comfort and a more natural way of movement. Justin also reminded me to look at the medical boots and the key problems they are solving and to consider if my design needs similar features but less intense.

On top of the tour to adidas, I also met with my mentor Shannon Pomeroy, a biomechanist working at Nike, a couple times to discuss my design directions, what factors I need to think about and how to get the essential data for the design. Shannon liked my restriction

system idea for the basketball shoe, but she pointed out that I should make sure the type of the thickness of material I choose are comfortable and don't cause any pinching into the foot. She also encouraged me to come up with a unique solution like this for my football cleats, since she thinks my current direction to solve for turf toe in football is on the right path but do not have my spin in it. I shared with her the changes I want to make to the last for heel spring, toe spring, and heel drop, and my concerns of how to determine the numbers for those. Shannon told me that without long term research and human subject testing the best way to do it is through research online, study the current product and make an educated guess.

After the meeting with Eric, Justin and Shannon, I had a clearer idea of the design direction I want to pursue and the key problems I want to solve. For both shoes, limiting the range of motion in a comfortable way at injured area of the foot is the top priority. I want to achieve that by adding additional parts like straps or force resistant structures, using materials that are best for the function of the parts, and allows the design to be more anatomically based. The second priority for both shoes is to modify the last. Last dictates a lot of the most important features of a shoe, like toe spring, heel spring, heel drop, the width and height of the toe box, etc. However, the current existing last for both sports are not designed for a comfortable fitting, nor satisfy athletes' special needs after the injury. Modifying the lasts can allow my design to achieve the functional purpose for rehab training. The third priority for the basketball shoe is the cushioning and stability of the midsole especially at the heel, to reduce shock to the Achilles tendon and avoid ankle sprain. For the football cleats the third priority is the plate design, especially with the flex zone and reduced traction of the studs.



Design Brief

Basketball training shoes designed to help NBA/ NCAA athletes who are recovering from Achilles injuries.

Consumer:

Elite/Sub-Elite Male Basketball Players

Environment:

Indoor Hardwood Floor

Season of Delivery:

Fall 2022

Retail Price: \$200

FOB: \$50

Customizable Option: \$350

FOB: \$87.5



Design Direction

Key Words:

Range of Motion; Protection; Stability

Features & Benefits:

Adjustable Flexion Restriction System prevents accidental over-stretching of the tendon

Higher Heel-Toe Offset reduces stress on the Achilles tendon

Increased Heel & Toe Spring offers a smoother transition for each step

Extra Cushioning at the heel lessens shock to the tendon

Wider Midsole provides more stability

Design Brief

Football training cleats designed to help NFL/ NCAA athletes who are recovering from turf toe injuries

Consumer:

Elite/Sub-Elite Male Football Players

Environment:

Indoor/Outdoor Artificial Turf

Season of Delivery:

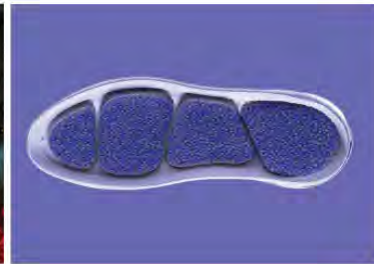
Fall 2022

Retail Price: \$160

FOB: \$40

Customizable Option: \$300

FOB: \$75



Design Direction

Key Words:

Range of Motion; Comfort; Support

Features & Benefits:

Flexion Restriction System at Forefoot prevents accidental hyperextension of the joint

Added Foam Midsole provides cushioning for the forefoot.

Decreased Toe Spring allows the foot to rest in the natural position

Wider Toebox avoids squishing the toes, also gives room for extra taping on the foot

Strategic Cleat Design reduces stress on the MTP joint

Ideation Process

At the initial period of ideation process, I was focusing on two tasks: 1. Figure out the toe spring and heel drop range that I want to use 2. Round one sketching to get the basic ideas out and some directions set.

To make my educated guess of the dimensions of toe spring and heel drop I first collected data from disassembling a few current products on the market. I then measured the generic lasts for different sports and try to understand the reason for the differences. I found out that sprinting last usually has the biggest heel drop and toe spring, for the forward propulsion. It is also very narrow. The basketball and football lasts are relatively flatter compare to a sprinting last or even running last, with a heel drop usually around 6mm. The basketball last is wider at the toe box than the football last and the basketball last has a higher toe spring as well, at around 17mm for men's size 9.

After getting the approximate range for the toe spring and heel drop, I then designed my own perception test to get the dimensions that I want to use. Due the different injuries I'm designing for, I was trying to achieve different things for the basketball shoes and football cleats with modifying the last. For the basketball last, I want a higher heel drop but not too high that is uncomfortable or dangerous, and I also want a slightly increased toe spring for better propulsion. I wanted to know how extreme the heel drop and toe spring can be without causing discomfort while stand still. For the heel drop, I cut out multiple the heel half shape of insole from Ortholite sample material in different thickness: 5mm and 3mm, then stack them to achieve different depth from 5mm to 15mm. As for the toe spring, I built forefoot plate with Rhino 3D in three different

angles from the base angle of 18 mm, which is similar to the current generic basketball last in men's size 9 and added increment of 3mm for the other two testing plates. Then I printed out the three plates for perception testing with the foam stack of heel parts. I asked a few of my classmates to stand on the forefoot and heel parts with different height combination and I also tested on myself to get a better personal feel as well. After collecting the opinions from the testing objects and considered my own perception and my design intention, I decided to make the basketball last with a 10mm heel drop, which balances the benefits to reduce the stress on Achilles tendon without compromising too much ankle stability, and a 21mm toe spring.

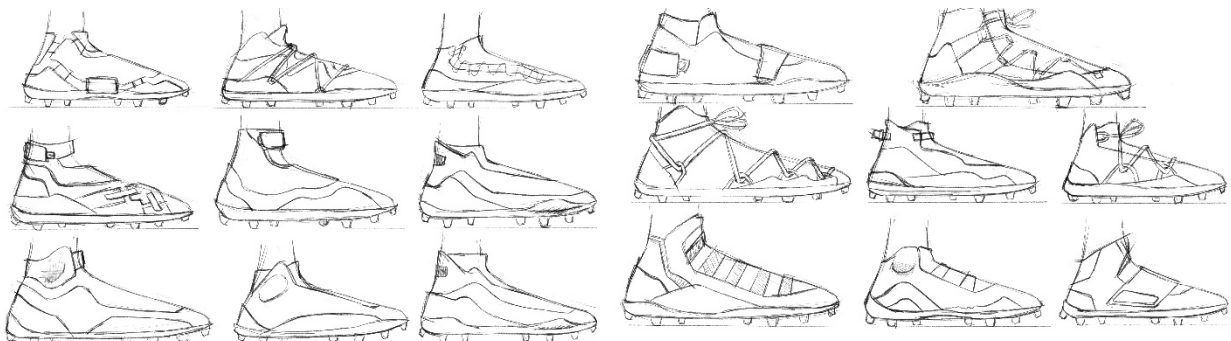
For the football last, I went back and forth with debating whether I should make the forefoot extra hard with a higher toe spring so that the MTP joint can stay stable while still able to perform its function in toe-off, or I should lower the toe spring to let the foot stay flatter when it's possible since toes are essential for balancing and raised toes can cause additional pressure on the MTP joint. But if I make the toes flatter, the toe off motion can be greatly impacted with an extra stiff plate. The solution I eventually came up with is using a flatter last to let the foot motion to be more natural, and adding a cushioning midsole which provide comfort to the forefoot and allows bending relatively easier, but including another mechanism that stop the dorsiflexion motion once it reach an allowed angle.



After settled on the direction of last modification and ranges of dimensions to use I went into Shoemaker and digitally adjusted my customized lasts in men's size 9. In addition to the toe spring and heel drop changes, I also extended the top of the basketball last to allow a higher top design. I set the height at 160 mm, just above the average length of Achilles tendon. And for the football last, I also made the toe box wider for better comfort.



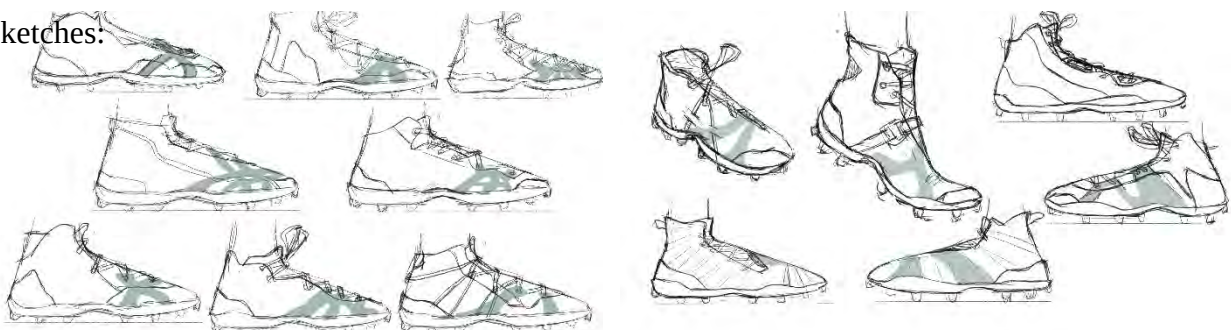
While figuring out the settings for the lasts, I also started sketching. At the beginning I was exploring in a more general direction with my design priorities in mind. For the football cleats I started with the general silhouette of the design. I wanted the design to be mid-cut, which

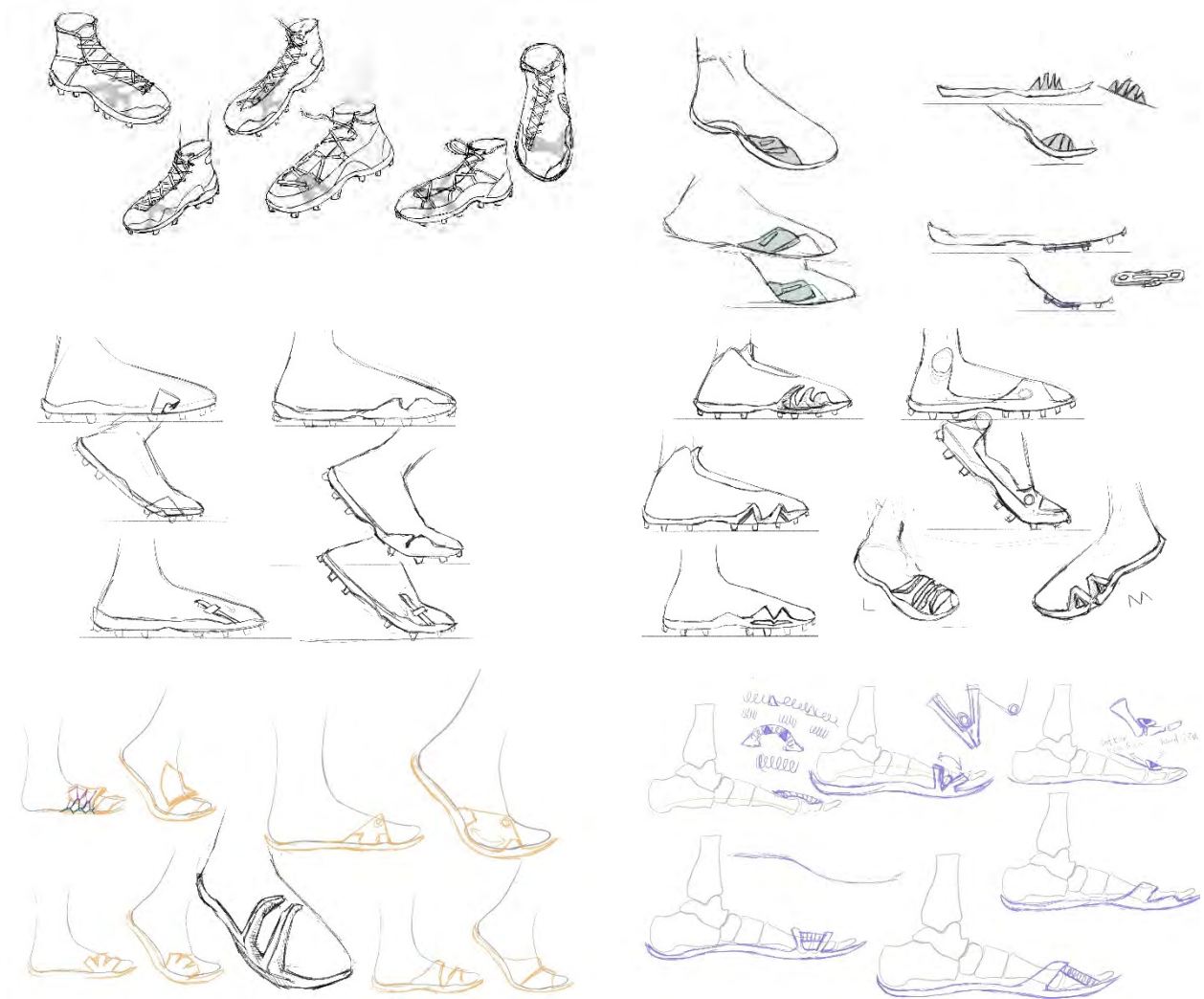


provides adequate ankle support without making putting on the shoe too difficult; I wanted to add additional support on the upper at the toe box, arch, and the heels but leave the MTP joint stiff material free. With those in mind I did these sketches:



After the more general exploration I started working on figuring out how to provide the constrained range of motion. One part is to use internal straps to secure the forefoot better, therefore I did some sketches for the shape of the strap. The other part is to create a structure that can physically stop the bending motion when the angle exceeds 60 degree. My initial thought was to extend the lateral side wall of the midsole onto the upper and give the structure enough thickness and some open space to allow the controlled bending. Here are some of the sketches:





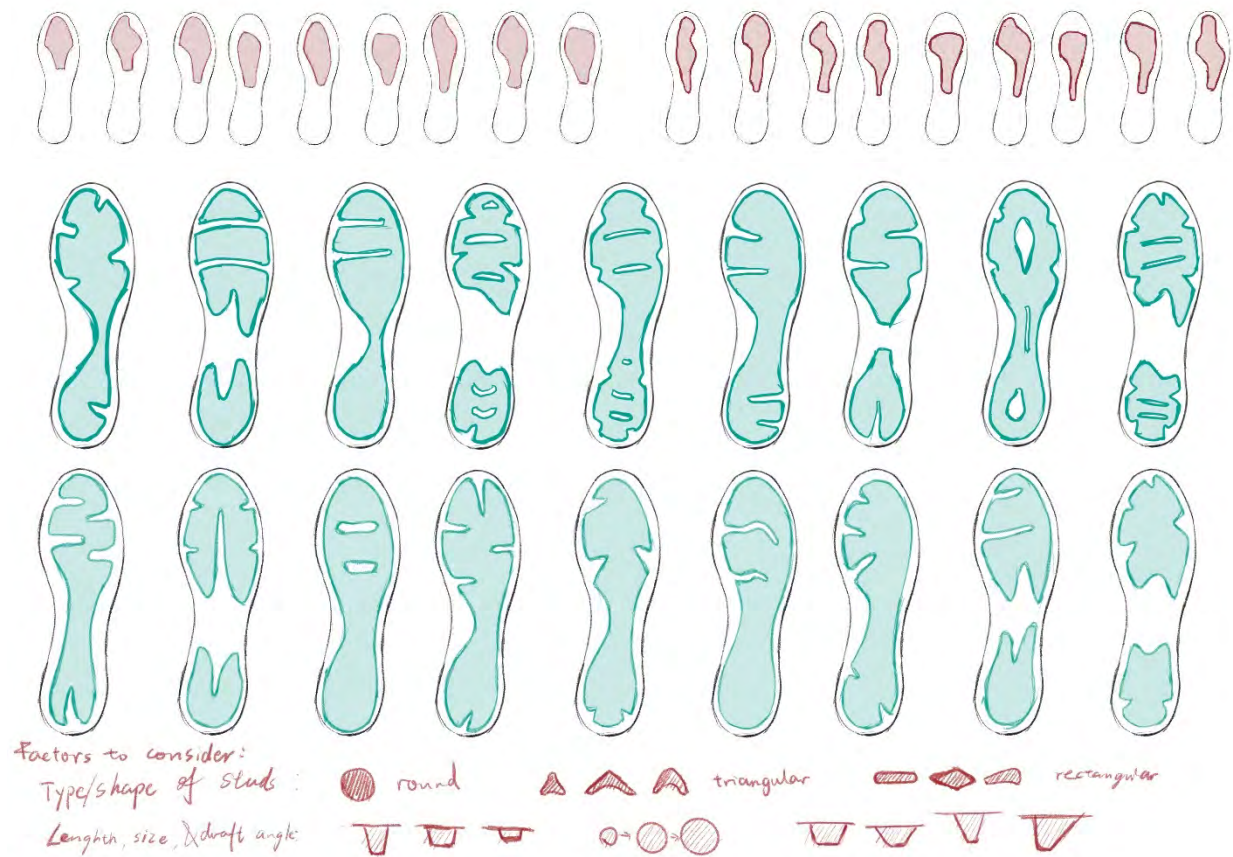
For the basketball shoes I also started relatively loose while considering the key design directions. I want to give the shoe a high-top silhouette with soft and thickly padding parts at heel rake. I know the shoe will integrate my solution to the motion restriction system, which I explored different shapes and combinations. Here are some of my first round of sketches for my basketball shoe design:



With my second round of sketching, I started with figuring out a better motion restriction system for my football cleats. I wanted to make something that's not been done before. After days of thinking and researching for inspiration, I came up with a duo stiffness concept which allows the forefoot to bend comfortably until the limited angle at around 60 degree. The concept

I created contains a cavity inside midsole where a carbon fiber plate is inserted, the front of the plate is fixed inside the midsole while towards the end of the plate some room was given for the plate to bend at different angle while the same force is apply and eventually when the bending exceed 60 degrees the carbon fiber plate will hit on the TPU plate under the midsole and slow down/stop the bending motion. Here are some of my second-round sketches for the football cleats:





For my second-round sketching of basketball shoes, I went more into the detail of the layering system of the shoe. I want the design to have a soft internal bootie with the strap that goes around the heel and top of the tongue, a stiffer outer layer and a flexible TPU cover that is removable. I explored different shapes and structures for different part of the shoes and ended up also want the heel counter to be part of the midsole foam, therefore given the shoe a thick and rounded heel for better cushioning and heel spring. Here are some of my sketches:



After second round of sketching, I had a better idea of the direction I'm following, and I started to make uppers to see how my favorite concept works in 3D and finalize the final pattern/design as I'm making the upper, since I prefer to look at the physical prototype and revise as I go. To make upper I taped both of my lasts first in order to get the pattern. I then made a few prototypes to help adjust the pattern to fit the last better. For the prototyping I used mock materials that are close to the properties of the final material that I want to use. Therefore, for the internal bootie/liner, I used spacer mesh for comfort and ventilation. And for the outer layer I used non-stretch mesh and synthetic material for better support. I also reinforced the key supporting area like the toe box and arch with hot melt TPU. For the football cleats upper, I chose the lateral side lacing to leave ample space on top of the MTP joint to avoid the pressure from the laces to cause pain at the injured area. Under the first layer of the upper a flexible yet non-stretch nylon strap is used to make sure the medial side of the forefoot is secured.

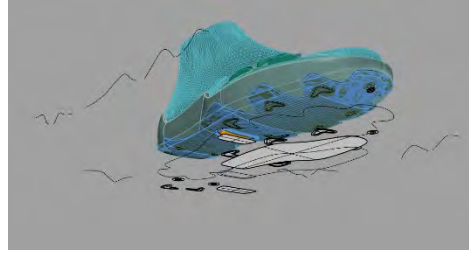
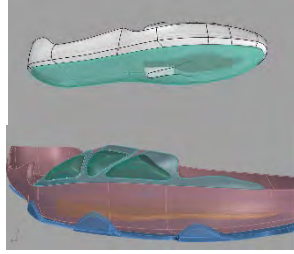
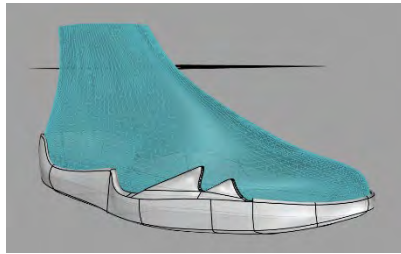
For the basketball uppers, I initially chose a side opened tongue. However, after a few trials I decided that the tongue design is a little too tricky combined with the layer system therefore I switch to a more traditional tongue that is attached to the bootie. I also increased the soft material area at the heel rake area to provide better comfort for the Achilles. The removable cover will be connected on both side of the shoe with nylon straps.

At the same time of making uppers I also used Modo and clay to help ideate the shape of the cover piece for the basketball shoe. The digital sculpting in Modo didn't work as well as I hoped but I still get some better sense of the direction I want to go with. Then I made a few models in clay to help me explore the form. The final cover will have support zone and flex zone. The support zone provides efficient force to resist bending, the flex zone allows the cover to bend to an outer direction therefore avoiding bending inside to pinch the foot.



Eventually I get to my upper design.





For the CAD part, I started with making the base shape of the midsoles and used 3D scan of clay models to help build the form digitally. I integrated parametric component on the cover of the basketball shoe and the plate of the football cleats to give them customizable solutions for individual athletes based on their size, weight, strength, foot pressure map and other physical information.



Third Round of Sketching and Prototyping:

At the beginning of the Spring term, I started the third/final round of sketching to finalize and connect the two designs better. I also decided to simplify the Tongue cover design for the basketball shoe.

Here are my sketches:





After Settled on the final design, I started prototyping. Other than upper making and CAD modelling that I have been doing, I also started printing out my 3d part and cast them with Smooth-On products. My goal was to make the final prototype as close to fully functional as possible. Therefore, I used the FlexFoam-iT! 17, a type of PU foam, to cast the midsoles, which is really close to how TPU foam in the market today feels like. For the outsole, tongue cover and stability cage, I used the Simpact 60A PU rubber. And for the football cleat plate I used Smooth Cast 61D semi-rigid plastic, and I also used the EpoxAmite 101 resin to wet-lay carbonfiber plate.

Here are some of my process picture:





And here are the final products:



Validation Plan(Original)

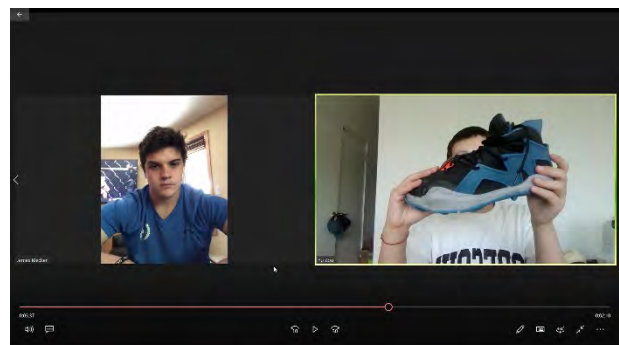
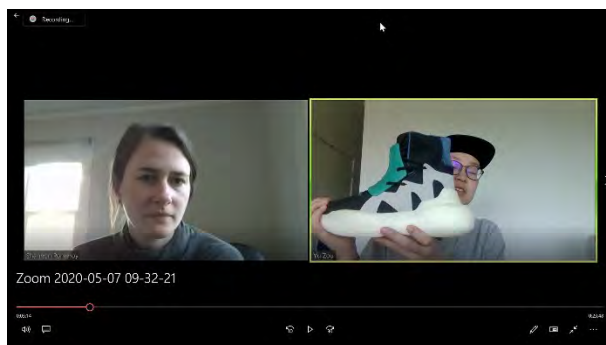
The validation plan of the new design must prove the key features of the products provide the function that they are designed for. The most important element is the flexion restriction systems that are specially designed for both shoes. To test the flexion restriction system for basketball, I want to perform a force gauge test and a perception/visual validation by biomechanics. For the force gauge test, I want to use smooth-on polyurethane rubber to cast my cover design and prove that when force is apply to bend the cover, sufficient amount of resistance are provided to slow down/stop the dorsiflexion motion. For perception/visual validation, I want to meet up with Shannon Pomeroy to see if she thinks the design can work from a scientist's point of view. As for the football cleats' flexion restriction system, similar tests will be applied. I will need to print and cast the midsole and carbon fiber plate for the testing. I want to prove that the system can provide extra resistance after bending exceeds 60 degrees. The football cleats will also be visually validated by Shannon Pomeroy.

Another important feature to be tested is the modified last. I want to see if the changes are noticeable when people put the shoes on compare to existing state of the art products, and how they feel about the difference. I want to invite a few classmates who wear men's size 9 shoes to compare my shoe with existing product and provide feedback on how they think of the different toe spring and heel drop in my design. They will be asked to answer on a scale from one to five, while one is very uncomfortable and five is very comfortable.

The third test will be for the traction of the plate/studs. I want to compare my plate design with current state of the art product to show that my design has less traction at the forefoot and allows more slippage. The force gauge test will be performed with 3D printed plate design of mine and a state of art product, while dragging them on a turf surface.

Validation (New)

Due to COVID-19, validation plan had to be changed to accommodate the special circumstances. Two perception validation was done through video chat on Zoom. The first one was with Shannon Pomeroy, biomechanist, to validation the biomechanics of the design. Shannon has confirmed that by theory the innovation should work, however, like all products, no one can be certain what is really going to happen without rigorous testing. The second perception testing was with James Klecker, Linebacker at the University of St. Thomas, to get athlete's feedback on how they feel about the design in terms of both function and aesthetic. James liked the design and thought that the focus on preventing reinjury can help speed up the recovery process.



Presentation Plans for Spring Term (Original)

For the final presentation at the end of the spring term I want to present my products in a minimalist display with well-organized hierarchy. The booth will have one table for general prototypes display as separated parts to help explain/present the features of each shoe (including uppers, midsoles, 3D parts, casted parts, etc.) and two pedestals for the two complete final products. An iPad or a TV screen will be used to play the 3D animation of the two shoes in

different colorways/material and different views with notation of the design features. I will be making and render the model as well as the video to showcase my 3D skill. I also want to design introduction/launch cards for both shoes in card stock at the size of a business card. The front of the card will be my rendered sketching of the shoe and the back will have a short introduction of the design in a couple sentences and key features in bulletin points. The cards will be put on the pedestals with the final products and let people to take the cards. Two boards will also be used to briefly address the problems that I was solving for, my research, my design direction and ideation process for each shoe.

Presentation (Real Life)

Due to COVID-19, the presentation is done online, therefore only digital aspects of the original plan were kept. I decided to take advantage of the online experience and spent more time on digital texturing and rendering of my final design, which was helpful for the presentation.

References:

Basketball:

- Cato, T., & Prada, M. (2019, June 11). *How NBA players have historically fared with Achilles injuries*. Retrieved December 8, 2019, from <https://www.sbnation.com/nba/2018/1/27/16940178/nba-achilles-injury-history-kevin-durant-golden-state-warriors-future>.
- Towers, C. (2015, June 1). *History not kind for ruptured Achilles recovery*. Retrieved December 8, 2019, from <https://www.cbssports.com/fantasy/basketball/news/history-not-kind-for-ruptured-achilles-recovery/>.
- Amin, N. H., Mccullough, K. C., Mills, G. L., & Jones, M. H. (2016). *The Impact and Functional Outcomes of Achilles Tendon Pathology in National Basketball Association Players*. *Clinical Research on Foot & Ankle*, 4(3). doi: 10.4172/2329-910x.1000205
- Amin, N. H., Old, A. B., Tabb, L. P., Garg, R., Toossi, N., & Cerynik, D. L. (2013). *Performance Outcomes After Repair of Complete Achilles Tendon Ruptures in National Basketball Association Players*. *The American Journal of Sports Medicine*, 41(8), 1864–1868. doi: 10.1177/0363546513490659
- Chinn, L., & Hertel, J. (2010). *Rehabilitation of Ankle and Foot Injuries in Athletes*. *Clinics in Sports Medicine*, 29(1), 157–167. doi: 10.1016/j.csm.2009.09.006
- RULE NO. 1: Court Dimensions – Equipment. (n.d.). Retrieved December 8, 2019, from <https://official.nba.com/rule-no-1-court-dimensions-equipment/>.
- Wheeler, T. (2018, December 18). *Achilles Tendon Injury: What Can I Expect from Treatment?* Retrieved December 10, 2019, from <https://www.webmd.com/fitness-exercise/treatment-for-achilles-tendon-injury#1>.
- Achilles tendon rupture. (2017, August 2). Retrieved December 10, 2019, from <https://www.mayoclinic.org/diseases-conditions/achilles-tendon-rupture/symptoms-causes/syc-20353234>.
- Hoffman, M. (2019, May 18). *Achilles Tendon (Human Anatomy): Picture, Definition, Injuries, Pain, and More*. Retrieved December 10, 2019, from <https://www.webmd.com/fitness-exercise/picture-of-the-achilles-tendon>.
- Achilles Tendon Injury in Basketball. (n.d.). Retrieved December 10, 2019, from <https://www.enerskin.com/blogs/blogs/achilles-tendon-injury-in-basketball>.
- Gallinger, Z. (2019, October 28). *The Most Popular Shoes And Brands Worn By Players Around The NBA - 2019 Edition*. Retrieved December 10, 2019, from <https://ballershoesdb.com/blog/popular-shoes-and-brands-worn-by-players-around-the-nba-2019/>.
- Langvin, E. (2016). *U.S. Patent No. 9,474,326*. Washington, DC: U.S. Patent and Trademark Office.

Petrie, J. G. (2014). *U.S. Patent Application No. 29/483,663*.

Kirschner, B. (2014). *U.S. Patent Application No. 29/483,711*.

Football:

Mares, A. V., Schreiter, R., van Eck, C. F., Blanc, R., & Musahl, V. (2016). *Management of athletic turf toe using biologics*. *Operative Techniques in Orthopaedics*, 26(2), 117-121.

Nery, C., Fonseca, L. F., Gonçalves, J. P., Mansur, N., Lemos, A., Maringolo, L., & Fonseca, L. F. (2018). *First MTP joint instability — Expanding the concept of “Turf-toe” injuries*. *Foot and Ankle Surgery*. doi: 10.1016/j.fas.2018.11.009

Poppe, T., Reinhardt, D., Tarakemeh, A., Vopat, B. G., & Mulcahey, M. K. (2019). *Turf Toe*. *JBJS Reviews*, 7(8). doi: 10.2106/jbjs.rvw.18.00188

Waldrop, N., & Smith, K. (2017). *Surgical Outcomes of Severe Turf Toe Injuries in High-Level Football Players*. *Foot & Ankle Orthopaedics*, 2(3). doi: 10.1177/2473011417s000402

Vopat, M. L., Hassan, M., Poppe, T., Tarakemeh, A., Zackula, R., Mulcahey, M. K., ... Vopat, B. G. (2019). *Return to Sport Following Turf Toe Injuries: A Systematic Review and Meta-Analysis*. *Foot & Ankle Orthopaedics*, 4(4). doi: 10.1177/2473011419s00429

Smith, K., & Waldrop, N. (2018). *Operative Outcomes of Grade 3 Turf Toe Injuries in Competitive Football Players*. *Foot & Ankle International*, 39(9), 1076–1081. doi: 10.1177/1071100718775967

Mccormick, J. J., & Anderson, R. B. (2010). *Turf Toe*. *Sports Health: A Multidisciplinary Approach*, 2(6), 487–494. doi: 10.1177/1941738110386681

Bowers, K. D., & Martin, R. B. (1976). *Turf-Toe*. *Medicine & Science in Sports & Exercise*, 8(2). doi: 10.1249/00005768-197600820-00012

Wheeler, T. (2017, October 24). *Turf Toe: Symptoms, Causes, and Treatments*. Retrieved December 11, 2019, from <https://www.webmd.com/fitness-exercise/turf-toe-symptoms-causes-and-treatments#1>.

Gamradt, S. C., & Brophy, R. H. (2009). *Managing turf toe in football players*. Retrieved December 11, 2019, from <https://lermagazine.com/article/managing-turf-toe-in-football-players>.

Brain, M. (2000, April 1). *How NFL Equipment Works*. Retrieved December 11, 2019, from <https://entertainment.howstuffworks.com/fb-equip13.htm>.

NFL. (2011). *Official NFL Playing Rules*. Retrieved December 11, 2019, from http://static.nfl.com/static/content/public/image/rulebook/pdfs/4_Rule1_The_Field.pdf

Football Positions Guide: Offensive, Defensive, and Special Teams. (2019, October 11). Retrieved December 12, 2019, from <https://www.sportsfeelgoodstories.com/football-positions-explained-offensive-defensive/>.

2019 NFL Rulebook. (n.d.). Retrieved December 12, 2019, from <https://operations.nfl.com/the-rules/2019-nfl-rulebook/>.

Anatomy of a Football Cleat. (2019, May 3). Retrieved December 12, 2019, from <http://athleteaudit.com/anatomy-of-a-football-cleat/>.

Foxen, T. (2017). U.S. Patent No. 9,615,621. Washington, DC: U.S. Patent and Trademark Office.

Walker, J. D., Dyer, C. W., Wright, Z. C., Maurer, M., Schiller, D., & Baghdadi, H. A. (2016). U.S. Patent No. 9,392,841. Washington, DC: U.S. Patent and Trademark Office.