

Project title: **Improving player safety from impact injury in cricket**

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INNERSTRENGTH

Cricket Body Protector



Project overview

The Product

The InnerStrength body protector is a wearable under-shirt garment which protects the user from cricket ball impacts to the chest, ribs, and abdomen. It consists of a base layer, with attached reinforcements: *sternum protector*, *rib protector*, and *lower torso protector*.

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The condensed rules of cricket



1
A **bowler** projects a ball towards the batter



2
Batter attempts to hit ball



3
Fielders try to prevent ball from going too far



4
Two **umpires** oversee the action

The problem | Initial research

The idea for the topic came from observing the modern style of batting in T20 cricket. The term **Power Game** is used throughout the project to describe this style of play. I wondered if it would lead to new impact injury risks and if a product could be designed to proactively combat them.

The Power Game explained

- Highly aggressive batting intent
- Ball hit harder more often
- Batter plays risky shots with less focus on defence
- Affects everyone on the field of play



Areas of exploration

Softball
Baseball
Body armour
Motorcycles
Superheroes
Bioinspiration
Phone protectors
Mattresses

W

What is the problem?

Impact injuries in cricket when a person is hit by the ball.
The ball is hard and travels at high speeds.

W

Where does the problem occur?

A cricket match, or in training (nets).

W

Who does the problem affect?

Batters, bowlers, close fielders, and umpires.

W

When is this problem present?

Scenarios in which elements of the Power Game are present.

W

Why is the problem worth solving?

An opportunity to improve safety, by predicting future risks.
Better protective gear makes the sport more accessible to new players.

Initial research findings

“More shots have more power”.

SOURCE Cricket umpires need specially designed helmets..., *ABC.net.au* (2016)

Umpires and bowlers are at increased risk, some have adopted custom protective gear.

SOURCE What is umpire Bruce Oxenford wearing on his arm?..., *Express.co.uk* (2017) / New Zealand: Mask-wearing cricketer expects more protection for bowlers, *BBC Sport* (2018)

Evidence suggests neck and chest protection can be improved.

SOURCE Traumatic cricket-related fatalities in Australia..., *Brunker, P et al. The Medical Journal of Australia* (2018)

Women's cricket is growing but manufacturers do not prioritise female gear.

SOURCE Women's T20 World Cup: record attendances and investment grows game, *BBC Sport* (2020)

T20 is the most popular format of the sport.

SOURCE Cricket has over 1 billion global fans..., *Rediff.com* (2018)

Recreational cricket participation is falling in the UK.

SOURCE Number of people participating in cricket in England from 2016 to 2019, *Statista* (2019)

Initial project GOALS

SAFER

INCLUSIVE

ACCESSIBLE

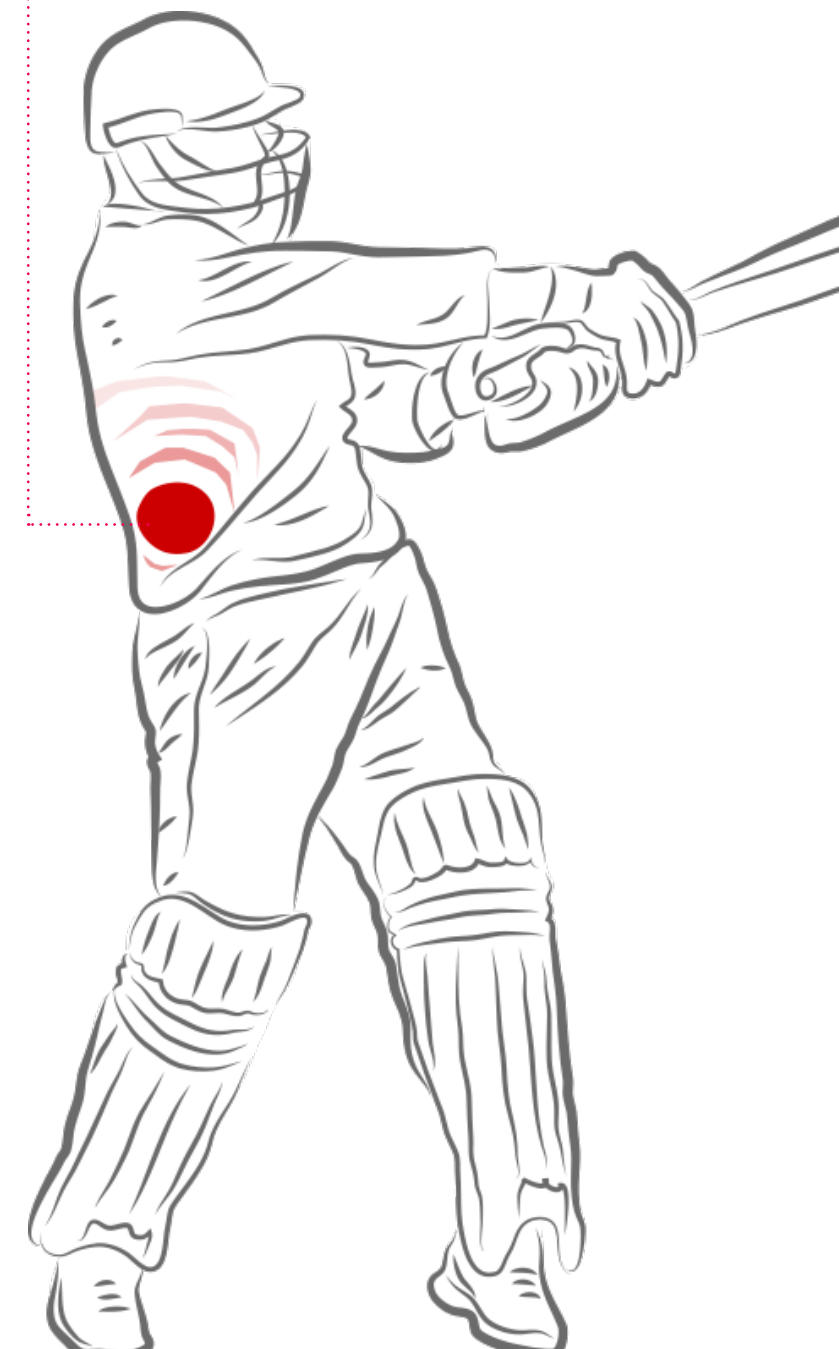


Cricket ball

Mass **160g**
Diameter **70mm**
Materials **Cork, twine, leather**

Harder and stiffer than a tennis ball.

Max. impact velocity **35m/s**
with an impact energy **98J**



Interviews

Interviews were conducted to understand the issues within the context of **amateur cricket**. In-person observation was not possible in the early weeks, necessitating an in-depth questioning approach, using the “5 Whys” technique to dig deep.

Themes

Importance of fit

Essential and optional gear

Effect of the playing environment

Underlying health conditions

Comfort versus safety trade off

REFLECTION

Insights provided by Alice highlighted a clear problem: **cricket manufacturers don't design for female players**. Female specific gear could have been the sole direction of the project. A lack of interviews with other Women's cricketers meant this was not possible, however this is a space I believe should be explored further.

Similarly, with a lack of umpires to talk to, I scrapped the focus on designing an umpire-specific product.

INTERVIEWS (Names changed)

MEDICAL

Khadija

GP, 5 years experience. Additional experience working in hospital urgent care.

Key insights

Impact injury affects a person's day job / Major organs are found in the torso area / Different bone densities and sizes, for males and females.

“Losing a small amount of function in shoulders, elbows or hands can have consequences on ability to do day job”

Sam

Junior Doctor, Northampton Hospital.

Key insights

Less bone strength at younger and older ages / Stomach area requires less protection than rest of torso / Vulnerability regarding hernia or post surgery scars.

“A less muscular physique or underlying issues like surgery scars can exacerbate the effects of a ball impact to an unprotected torso.”

CRICKET

Jeevan

2 years playing school cricket in India.

Key insights

Imitation of the best players / Poor fitting gear leads to low enjoyment / Environmental unpredictability.

“Fear is always a factor when facing the hard ball.”

Jim

Club secretary at a cricket club in Glasgow. 60 years of experience being involved with cricket.

Key insights

Gear evolution over decades / Club umpire characteristics / Lack of club cricket injury data / Chest guards rarely used

“What happens at the elite level cascades down”

Alice*

Scottish Women's cricketer. 17 years playing experience at club, regional and international levels.

Key insights

Difficult finding well-fitting gear / Unisex gear is a myth / Close fielders need to trust bowlers / Ill-fitting gear a catalyst for leaving the sport early

“Definitely feel that manufacturers should start creating women-specific ranges”

SOFTBALL

Holly

Softball player

Key insights

Softball specific protective gear / Sliding gear for abrasions / Importance of a good fit to performance / Fellow players adopting protective gear after experiencing an injury.

“Compression shorts are commonly worn for sliding.”

Bilal*

Lots of experience, national U-19 cricketer for U.A.E and now plays a high level of club cricket in UK.

Key insights

Finger injury frequency / Power game is present / Greater danger in training / Importance of aesthetic / Comfort vs safety trade off

“I can unequivocally guarantee that club players would not want to adopt an item if it looks strange or different.”

“Everybody gets hit on the helmet if they play long enough.”

Oliver*

15 years experience of village and school cricket.

Key insights

Near misses with square leg umpires / Schoolboys imitating scoop shots / Effect of temperature on concentration levels

“Physical confrontation is part of a bowlers armoury.”

* These interviewees agreed to be part of user testing

Research presented a large number of insights. The process of synthesising the information, helped to solidify a core set of design opportunities.

Six increased impact injury risk scenarios

The scenarios where risk is increased and feeling of vulnerability is heightened. Formulated from research findings.



1 **Batting** against fast, short-pitched bowling.



2 **Batting** on a pitch with uneven bounce



3 **Fielding** close to a power hitting batter



4 **Fielding** on an uneven or hard surface



5 **Bowling** to a powerful batter in training



6 **Attempting** to play scoop shots when batting

DECISION

Focus on **batters** and **fielders** as the most beneficial users of the product.

Key insights

- 1 **Elements of the power game** are present in amateur cricket
- 2 **Adoption** of cricket gear is based on **trade-offs** evaluated by the user
- 3 **Gear aesthetic** is important to amateur players
- 4 **Poor fitting gear** has negative effects on comfort, performance, and enjoyment
- 5 Ball impacts in the **gaps between items** of gear leads to pain and bruising
- 6 Amateur players **imitate** elite professional players
- 7 Player **sliding** leads to **abrasions** which can be painful for days
- 8 Repetitive **finger injuries** are a problem for players
- 9 The **torso** is mostly **unprotected**
- 10 Current batting gear is designed for a **side-on batting technique**

Design opportunities (ranked)

Protecting unprotected areas.

Custom tailored batting gear for a better fit.

Women specific batting gear

Umpire/bowler head protection

Finger injury prevention / on-field recovery.

Chosen concept (at interim presentation stage)

Torso protection for fielding and batting. Focus on batters and fielders as they are the main stakeholders within the danger scenarios. Separate male and female versions to account for issues with unisex gear. The design should recognise the need for well-fitting protective gear.

Research indicated that an interventive design will most likely be adopted by a cricketer with **beginner or moderate experience**. They are more likely to feel anxiety and vulnerability when exposed to the risky scenarios.

Personas

The interviewees who played cricket helped to paint a picture of their personal experiences when new to the sport, and also observations and stories of inexperienced teammates, which helped to form a set of personas.

**James and Martin can be considered “extents” falling outside the targeted user profile but their issues are essential to how I think about my design. It is useful to understand how the design could be adopted by those outside the user group.*



James, 17*

A young player enamoured with the audacious shots played by A.B. de Villiers. Has practised scoop shots in a controlled coaching environment and now wants to unleash it in games.



Tariq, 22

Novice hard ball player who has played for fun with tennis balls and at school. He is now looking to make the jump to club cricket. Finds the nets a bit daunting.



Lisa, 25

Frustrated as she is struggling to find gear that fits. Beginning to feel she just needs to get used to the discomfort.



Mo, 31

Has been playing since 12, and is an ace close fielder, known as being fearless, but has recently been injured in the nets and feels uncomfortable returning.



Martin, 42*

Recently had abdominal surgery. Loves batting, hates fielding. Enjoys the Sunday match environment, but feels like an extra protective barrier is now needed.

User profile

Male / Female
Age: 18 - 32
Lives and plays in UK
Stature: 5% Female - 95% Male
Playing experience: <10 years

An amateur cricketer who plays twice a week during the spring and summer months. Works full time Monday-Friday.

Image conscious. Wants to buy gear once that lasts a long time. Plays for fun and self improvement.

Use environment

Weekend matches
Training (nets).
Indoors and outdoors.

User needs (ranked gold, silver and bronze)

“ <i>I don't want a serious injury</i>	“ <i>I want gear that fits well</i>	“ <i>I want to feel safe when playing</i>		
“ <i>I want to run, throw and bat in comfort</i>	“ <i>I want gear that is quick and easy to put on</i>	“ <i>I don't want the ball to hurt me</i>	“ <i>I don't want my gear to smell bad</i>	“ <i>I don't want gear to dig into my skin</i>
“ <i>I don't want to wear something that looks strange</i>	“ <i>I want gear that is light and easy to bag</i>	“ <i>I don't want to overheat</i>		

Design requirements

Fits well. Tailored and contours to body shape and size.

Lightweight. Similar weight to a chest and arm guard combination.

Mobility. User feels comfortable when performing all cricket body actions.

Protection from impact. At max. impact velocities 35m/s (male) and 31m/s (female):

Protect the chest to prevent serious blunt force trauma
Protect the ribs and arms to prevent fracture and reduce bruising.
Protect the abdomen to reduce bruising and pain

Easy to don. Can be put on in under 10 seconds.

Male and female sizes. XS, S, M, L, XL. Accommodate 5% - 95% body sizes.

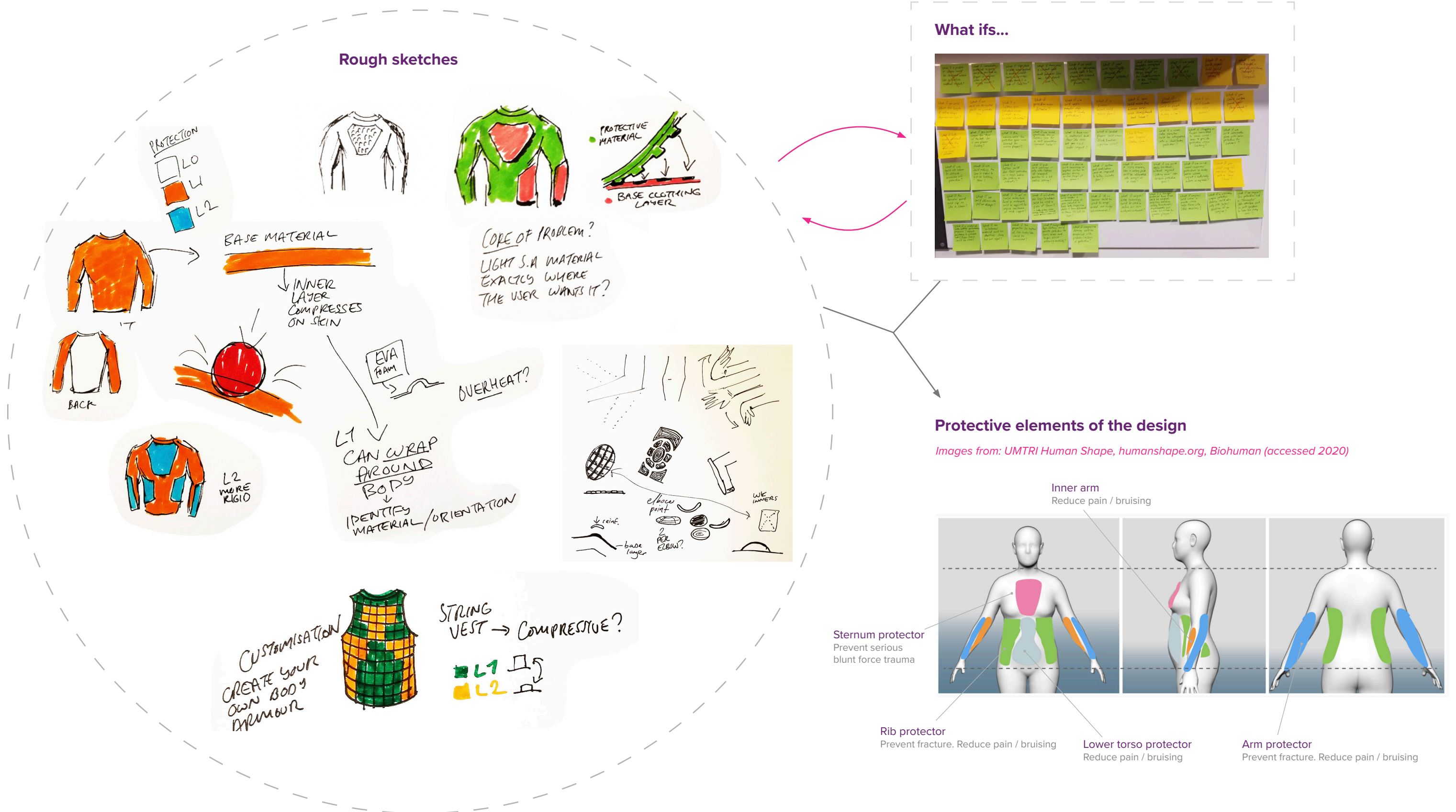
Hand or machine washable.

Withstand 100 impacts during a minimum 10 year lifespan.

Ventilated materials. Important due to match durations and the heat of batting.

Concept ideation

With the body protector concept established, the next stage included sketching of visual ideas and recording **What if...?** post-it notes. This helped to develop the prospective components within the design.

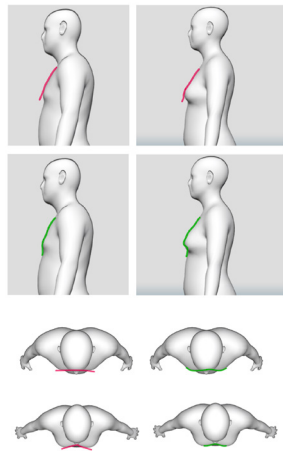


Prototyping

Each protector piece was initially worked on separately, during weeks 6-8. Self-testing based on 50% male stature.

Sternum Protector

Initial sketches



Images from: *UMTRI Human Shape*, humanshape.org, *Biohuman* (accessed 2020)



SP1.1

Length extended so the piece starts below sternum notch and extends past xiphisternum.



Too wide at the top, interferes with shoulder motion. Too rigid and flat.



Curves added for comfort and fold to allow bottom flap to contour.



Weight and geometry satisfactory. Improve comfort and contouring.

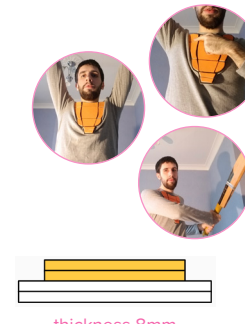


SP3.0

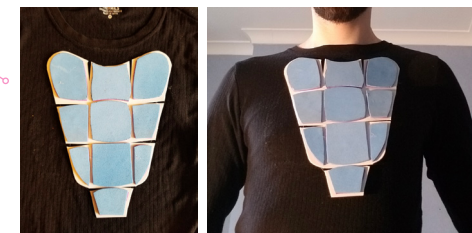
Attaching a cricket inner thigh pad piece of polyurethane foam. Comfort, contouring and feel was good. Single mould with 4mm base and 10mm protrusions (gap 2mm) (further explored in versions 4 and 5).



SP4.1



thickness 8mm



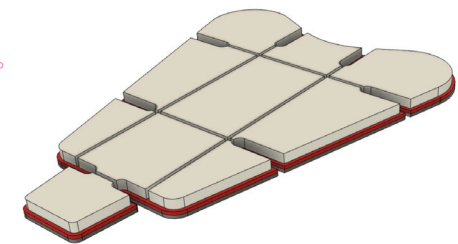
SP5.2

Inspired by petrol tank key protectors, indents cut out of the base layers to ensure contouring to body



Lessons learned

Ideal thickness 6-8mm
Contour to 2 planes
Base layer with indents
Width should not inhibit shoulder motion
Design to take forward SP5.2



CAD modelling based on SP5.2. Explore larger thicknesses and details regarding the form of the protrusions.

Establishing geometry and area of coverage. Cardboard, electrical tape, thermal base layer

Simulating likely colours, form, thickness, and materials.

EVA foam layers and adhesive. Testing body motions: stretching, raising arms, playing cricket shots.

Rib Protector

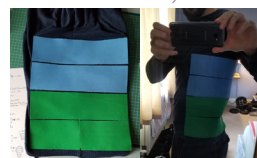
Conceived as protecting ribs, side of torso, and hips



RP2.0

Rigidity made it very difficult to don.

More, smaller pieces



RP1.0



RP3.0



RP3.1.2

Establishing geometry and area of coverage.



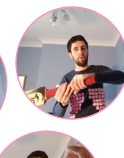
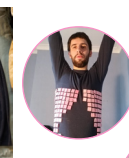
RP6.1.1



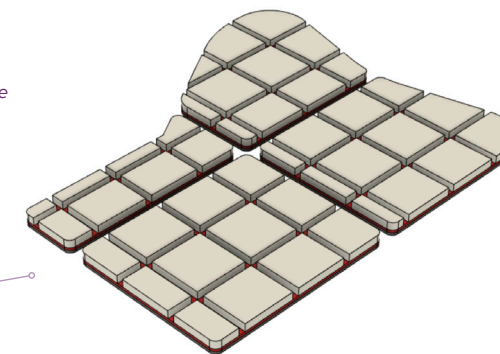
Tucking it in helps it feel secure. Decent range of motion and felt comfortable after 5-10 mins testing.



RP7.0



Ideal in terms of comfort and mobility. Impact effectiveness unclear.



CAD modelling based on best qualities of RP6.1.1 & RP7.0. Larger surface area of protrusions but two key gaps: vertical and horizontal, to ensure mobility

EVA foam layers and adhesive. Testing body motions: stretching, raising arms, playing cricket shots.

Lower torso protector

Simplest aspect of design. Inspired by mattress protectors and inner gloves



No physical prototyping but potential materials were identified: polyethylene foam, memory foam.

Arm protector

Began initial prototyping but twin concerns of ensuring wrist and elbow mobility, for both batting and fielding, became too complex and unfeasible in the time constraints.



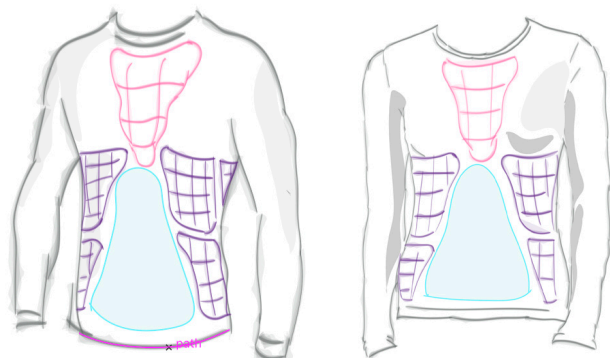
DECISION

Remove arm protection as a design requirement.

User testing

Prototypes sent to testers, consisting of sternum protector and rib protector. Each tester provided a desired size for the base layer. Velcro was used to attach the foam pieces to it.

Integrated body protector



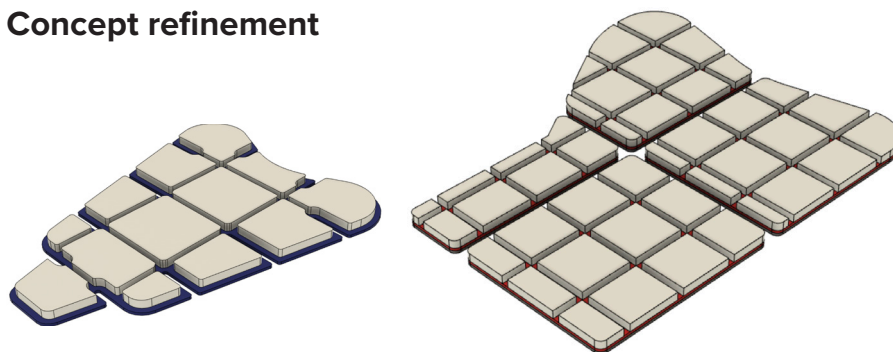
Anthropometrics (sternum protector example)

50% male geometry established through prototyping. Width of sternum protector is 50% of **average shoulder width**. Using the *Table for Estimated Percentiles* (Tilley & Associates, 1993), average shoulder width for the key percentiles were obtained. Ratios can be calculated for scaling up/down the 50% (medium) male sternum protectors to nine further sizes, for male and female.

Body protector sizes and their percentile representation					
Size	XS	S	M	L	XL
Percentile stature	5%	25%	50%	75%	95%

ISSUE Research indicates unisex size medium is effectively male size medium.

Concept refinement



Comfortable and mobility both good. Not considered essential protection.

Minor comfort issues, but it needs to be thicker.

New versions of the working design need to be thicker to fully protect. Mobility will be hampered and more crumpling is likely to occur.



Smaller foam pieces attached directly onto base layer but not as small as above. Dependent on material selection.

User 2 (Bilal) Prototype (male, size: M)



FEEDBACK

Would be a handy product for experienced cricketers for batting and fielding very close (2-5m). **He believed that the pieces were supposed to be detachable and found this an excellent feature.** He would remove one side of the rib protection and the sternum protector when batting. Donning was straightforward. Comfort and mobility were good.

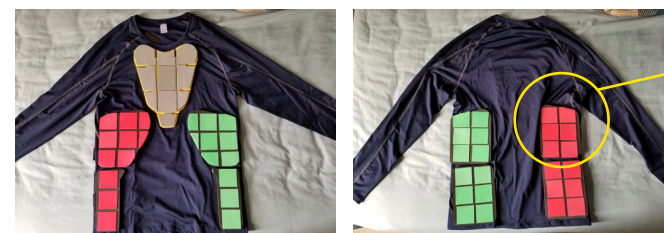
Improvements suggested

Adding shoulder protection (region indicated in photo) Foam needs to be thicker to give feeling of safety.

Key insights

Base layer should be white if used in UK club cricket. Having detachable pieces would be very useful.

User 1 (Oliver) Prototype (male, size: XL)



Mobility issue
"When bringing my arms back (when running) it catches slightly on the upper back pad".

FEEDBACK

Impressed with the concept. **Donning was easy up to a point, with the lower foam pieces "catching at the final point of putting on"**. Fit was tight around rib and lower back, so he would be "inclined to try a larger size". When sitting, the sides "crumpled into themselves".

Weight, low neckline and sternum protector (shape, position, coverage) were all positives. Rib protectors would be very helpful against quick bowlers, happy with the coverage. Issue with "friction at the end of a pull shot". No issues with fielding related motions (throwing, bending, ready-stance) but **would likely only wear it on the field for close positions**.

Improvements suggested

Thicker foam padding.
Protectors sewn into the fabric (more secure).
Elbow padding for batting and diving in the field.

Key insights

Base layer should be white.
Good level of comfort and mobility in general.

User 3 (Alice) Prototype (female, size: XL)



Improvements suggested

Protectors sewn into the fabric. More secure velcro attachment and detachment. Multiple colours for both red and white ball cricket.

FEEDBACK

The quality of the prototype was poor, with the protector pieces unable to stay secure to the base layer. As a result, many of the tests were not possible. It felt lightweight which was a positive. Likes the concept and product idea, "particularly for fielders".

Key insights

Fit needs to be tight to be effective. Rib protection is more important higher up.

Sternum protector mobility requirements mean current SP design doesn't have to change but I want a consistent design...

Materials

Protection aims to be thinner, composed of smaller pieces. Requires an improved impact absorbing material combination than commonly used Polyurethane foam

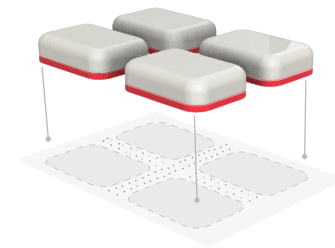


Datum material (14mm)

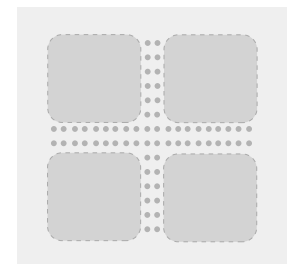
Crickets inner-thigh pad. 12mm thick polyurethane foam (100kg/m³) protrusions, on 2mm EVA foam. 3mm gaps between protrusions.

GOAL Same level of impact protection as datum with total thickness reduced to 10-12mm.

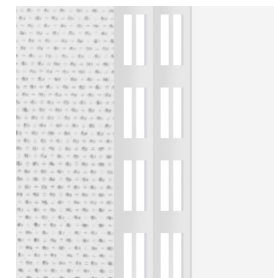
Base layer attachment



Reinforcement for the sternum and rib protectors consist of die-cut foam absorber pieces **glued to base layer**. They are spaced out in gaps of 5mm or 10mm to help mould around the body profile.



Base layer is flexible with a back mesh panel. Foam absorber pieces are glued onto non-mesh areas of fabric. Small perforated holes in the gaps provide ventilation.

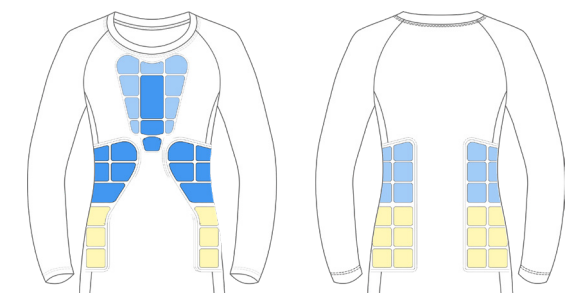
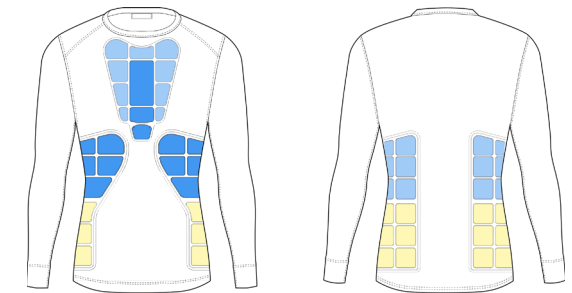


Mesh outer layer stitched on top to keep the foam pieces secure and prevent edges peeling off when sliding, or in the washing machine.

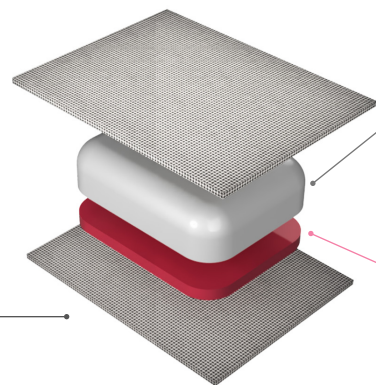
Vinyl Nitrile thickness

Silicone layer is 2mm, the vinyl nitrile foam thickness varies depending on body area under protective coverage. Bony areas like sternum and ribs require more protection.

● 10mm ● 8 mm ● 6mm



Chosen material combination



Vinyl Nitrile foam (6-10mm thick)

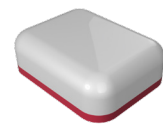
Excellent impact properties. Applications in body protection. Adherence to a number of impact testing standards for blunt trauma. **9 times stronger than polyurethane and absorbs less water.** Perforated for ventilation.

Silicone Gel sheet (2mm)

Shock absorbing cushioning layer. Dampens shockwave impact and provides comfort to skin from the harder Vinyl Nitrile foam.

Polyester / Elastane base layer

Soft, light, and flexible. Compressive. Absorbs moisture. Sportswear applications,



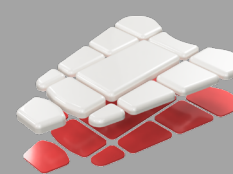
The foam absorber piece

Glue interface, both materials have good adhesive properties.

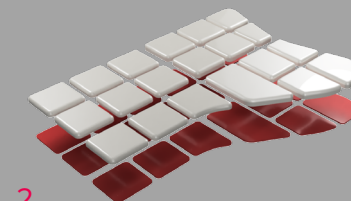
INNERSTRENGTH

Cricket Body Protector

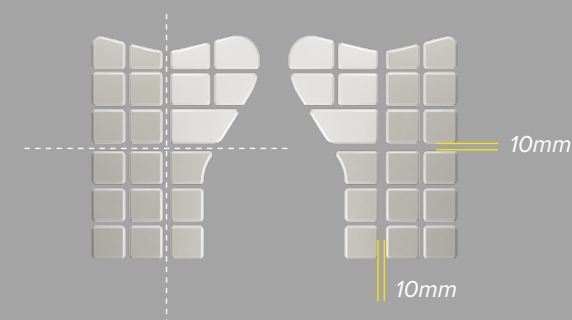
Mesh back panel for ventilation



1
Sternum protector
5mm gaps between the foam absorber pieces. Geometry carefully chosen to aid in contouring.



2
Rib protectors
10mm gaps enhance mobility for actions like throwing, bending, twisting. Extra reinforcement (12mm) located at the front. Sides are less reinforced, their thickness



3
Lower torso protector
Polyethylene foam sewn into the front of the garment. Stitching pattern for stability and to avoid crumpling. There is further potential for finding a foam with properties that keep the user cool.

The product

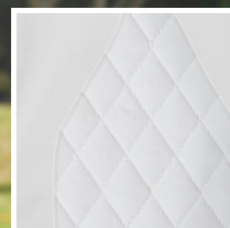
In-use.

Zain Mahmood - MSc PDE Major Project
Design Process Journal - 11th August 2020



Sternum protector

Protection from blunt force impact trauma to chest. Adds a level of psychological safety when **playing scoop shots**, or when players **field close** to the batter.



Lower torso protector

Small level of **cushioning for stomach impacts**, reducing pain and bruising.



Base layer

Thermal regulating base layer material. Ventilation mesh panels in the back.



Rib protector

Symmetric design for right and left-handed batters. Prevent fractures when facing fast short bowling or fielding close.

TASK

Batting in a Saturday club match. Good sunny conditions for batting but the opposition has a couple of fast bowlers...

TARGET OUTCOMES

Feel safer. Play shots confidently.

User interactions on match day



Putting on



Tuck into waistband of trousers



Put on outer cricket white layers

If batting



'Pad up' with batting gear

TASK

Batting (above)

If fielding

TASK

Fielding



Post-match



Washing machine

Thoughts on project management, and lessons learned.

Removable attachments

Compression base layers may get really hot and uncomfortable if fielding further out in the sunshine. The idea of being able to customise level of protection based on where you are fielding at the time is interesting. Is there a way to do so without constantly leaving the field?

Branches in the design process

It is not a waste of time to go down paths of exploration which are ultimately not used in the final design as the knowledge gained can be used in future projects. Sometimes, brainwaves for ideas came later on in the process and it was frustrating to not have the time to explore them further.

Synthesis

Regular tutorials and presentations motivated the need to synthesise past work and clearly present what is necessary. These mini deadlines were very helpful in facilitating backcasting and staying organised.

Male and female design

It was difficult to explore male and female perspectives at the same time. In actuality, I created a male product then made adjustments bases on size data. Adjustments to protector thickness and adapting geometry to the female body shape are both necessary amendments that needed to be made. I had the figures to validate differing thicknesses, but not the in-person information needed to better understand the problem.

Conclusion

I was encouraged that my two testers who are experienced players enjoyed the concept, particularly for batting and (very) close fielding. It wouldn't surprise me if umpire, bowler and "scooping" injuries become a bit more common-place in the coming years. Perhaps coaching and safety requirements are just as important as physical devices but there is no doubt that understanding of materials and physical characteristics of impacts is key to keeping players and umpires safe in the long run.

Zain Mahmood



References

References specifically cited in this document are below. Full list of project references can be found in the technical report.

All images are self-captured, purchased (from Shutterstock) or from royalty free websites (Pixabay, Unsplash)

1. The problem / Initial research

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