STEPUP

Enhancing Performance for Badminton Players

Industrial Design Report

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Badminton Player Monitor System

by

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Submitted in partial fulfillment of the requirements for the degree of

Bachelor of Industrial Design

Faculty of Media and Creative Arts

Humber Institute of Technology and Advanced Learning

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April 19, 2024

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Abstract

Badminton is a very popular sport, one of the most played sprots in the world. It requires very little equipment and can be played any time of the year without needing special skills for the amateur player. However, when it comes to teams, tournaments, and competition it involves a great deal of training. Since badminton is a non-contact sport most don't believe, it can lead to injury, however this is not the case. Multiple studies have been done to show an average of 3.5 injuries per 1000 playing hours (Marchena-Rodriguez, Ana, et al, 2020). Most of these injuries are caused by overuse of the body, specifically in jumping actions and quick changes in direction. It is very difficult to monitor the use of the body while playing, this distracts from the game itself. A player must focus on where the shuttlecock is and the position of their competitor, this is more difficult in doubles. That is why injuries go unnoticed until it is too late, most prevent any court time for 3 months. A solution will be developed to monitor the movement of a player without distracting them from the game.

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to everyone who contributed to the completion of this project. First and foremost, I extend my heartfelt appreciation to my professors and advisors, whose guidance and expertise were invaluable throughout the process. I also want to thank the professors and fellow classmates for their dedication, hard work, and collaboration, without which this project would not have been possible. Additionally, I acknowledge the support of The Humber College Institute of Technology & Advanced Learning, whose resources and encouragement significantly contributed to the project's success. Lastly, I extend thanks to all those who provided feedback and support along the way. Your contributions have been instrumental, and we are truly grateful for your involvement.

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1 CHAPTER 1 PRODUCT DEFINITION

1.1 PROBLEM DEFINITION

This section focuses on defining the problem of the thesis project. The beginning starts here, addressing what the main problem is and why it is important. Leading to the information the needs to be gathered to determine what must be asked. Finally going into the history and social context of the problem at hand.

1.1.1 Problem Definition

Badminton is a fun interactive sport regardless of whether it is played for fun or for competitive reasons. However, it can be difficult trying to improve one's performance during a game. If one focuses on their own performance their attention is then taken away from the actual game. It is even difficult for a coach to look for areas to improve as they must focus on the same things as those on the court. During a game there is limited time for a coach to communicate with their players. Most feedback can only be received after a game, which makes improving during play almost impossible. Coaches also look for weaknesses in the opponent's play and create a plan on how to take advantage of that. This forces a player to weigh which is more important, their improvement or their opponent's weakness. During competitions players tend to take any advantage they can, this leads to a higher risk of injury. Most common injuries are to the ankles, knees, and lower back (Kaldau, Niels Christian, et al, 2021.). As players cannot be switched out in badminton, they tend to play through the pain but end up making the injury worse. This provides an opportunity to design a system that can monitor players and quickly give out information.

1.1.2 Rationale & Significance

Current methods of what is used to monitor performance of a badminton player need to be determined. How effective are these methods and what areas of performance do they monitor. What information takes president over others and how is that chosen. What is allowed during training versus during competitions. What players have access to regarding amateur level and professional level. Does the different environments have different effects on the player's performance. What is the most common environment in badminton, which provides the most benefit. Is there anything set up so medical teams have quick access to a player's medical history.

1.1.3 Background. History, & Social Context

Text begins as a new paragraph. Battledore and Shuttlecock, now known as badminton, originated in Ancient Greece. It quickly spread to China and Eastern India, where the net was introduced. British army officers stationed in India brought it back to England with them. At that time, it was only the upper class that was allowed to participate, now anyone can play badminton. By 1992, badminton was an official Olympic sport with 5 medal categories. The type of equipment grew over time, originally with a wooden racket, then lightweight steel, and now graphite or carbon fiber. This made the racket more lightweight so more power could be used. Footwear changed to provide more agility on the court. Training focuses on all round physical development than techniques. In training only plastic shuttlecocks are used as they are more durable than the traditional kind. Only in competitions and tournaments are the original shuttlecocks used, they are made of feathers, they are also known as "birdies". The reason that there are so few monitoring systems used is because no technology is allowed in competitions. Only during training are most wearable or off-court systems used.

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Summary

Badminton is an extremely popular sport played all over the world, yet little is used to help players improve their performance. With so many things to focus on during the game, players and coaches alike are forced to ignore their physical state. Feedback from coaches tends to relate more to weaknesses of the opponent than the player's performance. This leads to a higher risk of injury to the player, mostly due to jumping and quick changes in direction. In badminton players cannot be switched out, so they tend to play through pain. It often gets to the point where the injury is so severe that the player requires 3 months to fully heal. It must be determined what methods for monitoring are currently being used. What is the difference between these methods during training versus competitions. How might the different court environments benefit or interfere with a player's game. The equipment has evolved over time, but how do they prevent injury. Current monitoring products are not allowed during competitions. Most products on the market allow for more power and faster movement, but nothing helps with the physical state of the player.

CHAPTER 2 RESEARCH

2.1 USER RESEARCH

The goal of this research is to understand the user to discover their main needs and have a human-centered design. This includes all stakeholders relating to the sport such as the player, coach, medical team, and sponsors. The research methods used in this section are user observation, 1:1 interview, and literature review.

2.1.1 User Profile - Persona

Figure 1 - USER PROFILE PLAYER

Name	Mitchell Allen
Age	26
Occupation	Credit Analyst
Income	+$60,000
Education	
Family	Married
Location	Mississauga, ON
Main Hobbies	Badminton Club, Camping, and Tennis Team
Frequency	Badminton Club (3+ times a week), Camping (4+ times a year), and Tennis Team (2 times a week)
Social	Mostly with family, friends, and badminton team

Table 1 - USER PROFILE PLAYER

Coach

Figure 2 - USER PROFILE COACH

Name	Robyn Price
Age	35
Occupation	Badminton Coach
Income	+$50,000
Education	Graduated Humber College's Fitness and Health Promotion program
Family	Married with one kid
Location	Mississauga, ON
Main Hobbies	Badminton Club, Hiking, and Cooking Classes
Frequency	Badminton Club (3+ times a week), Hiking (4+ times a month), and Cooking Classes (once a week)
Social	Mostly with family, friends, and badminton team

Table 2 - USER PROFILE COACH

The users are divided into different categories such as primary, secondary, and tertiary depending on their relation to badminton. A player and their coach are primary because they have the most interaction with the sport. Secondary is the medical team, as monitoring the player's movement is critical information in case of injury. Then tertiary are sponsors of the game, they develop the equipment used by players and desire for them to succeed. Badminton does not have a specific demographic and can be played by anyone. However, it is extremely popular in Asian and Scandinavian countries where players tend to start at a young age. Very little equipment is required if one is playing recreationally, where various age groups participate. There is a smaller demographic when played competitively. The

common age for competitive playing is late teens to forties, although regarding injuries those in the twenties are most at risk (Phomosoupha and Laffave, 2020, pg. 189-99). Most players have about nine years' experience before injuries start to occur. The biggest challenges are maintaining physical fitness, health, and being able to practice. The most important elements of badminton are stamina, speed, and power; these require a variety of training technics to excel. Proper footwork, arm swing, and hand-eye coordination are critical which require practice at least two-three times a week.

2.1.2 Current User Practice

Common practice for badminton players getting dressed, equipment checks, one-on-one with the coach, warm-up, stretches, and then the game starts. Wearing the proper attire is important to allow one's body to breathe and move easily around the court. A player's racket must be maintained for the best use out of it, shuttlecocks and nets are checked by the referees to make sure everything is up to standard. Speaking to the coach before a match is important as there is little opportunity once the game has begone. A coach provides important feedback to the players and helps motivate them. Then a player must warm their muscles with a quick practice match between teammates. Stretching is very important, focusing on the main joints to lower the risk of injury. Once the game begins a player only has two opportunities to speak to their coach, during a timeout and halfway break. For training, that can depend on a player's strengths and weaknesses. Coaches adjust training per player as everyone will have different requirements. Common training drills are footwork, smash practice, and net play drills focusing on the three most important movements. Footwork is needed so players can use speed and stamina to move in any direction. The main exercises for this are shuffling, back and forth movements, and zigzagging. Smash practice helps with speed and power, the goal is to hit the shuttlecock, so the opponent does not have enough time to reach it. This also helps with hand-eye coordination, so the shuttlecock goes where the player is aiming. Net play drills are used to hit the shuttlecock just over the net, making it difficult for the

opponent to reach it. This is often used once the opponent has moved the back of the court. Training is a common activity and is required to stay in shape.

The main method of interviews were in-person interviews and over-the-phone interviews. The interviewees had various backgrounds and experiences with the sport of badminton. Some were professional players, recreational players, and coaches. Questions during the interviews did change to some extent depending on who was being interviewed. The data gathered was very helpful in designing a product that would benefit both players and coaches.

Interview Questions for Players:

- What motivates you to play badminton?
- What is your experience with the sport?
- What are the 3 biggest challenges in your opinion?
- What are the 3 main activities you do in relation to badminton?
- Please list some of the equipment you enjoy using.
- How do you maintain your equipment?
- Please explain your communication with your coach and other players.
- How do you monitor your improvement?
- What are some common training techniques you use?
- Please explain your medical history

Figure 3 - PLAYER LANDING

Key Takeaways – Interviews were conducted over the phone or in-person

- Players are willing to risk injury.
- Common movements like jump shots, lunges, and dives put unnecessary stress on the body.
- Most players started playing badminton as children.
- Their main need is to stay physically fit. Focusing more on reaction time, footwork, hand-eye coordination, and wrist movement.
- Access to practice time can be difficult to come by.
- The biggest challenge is keeping one's body at a high level that can participate in a fast-paced sport.

-

Figure 4 - PLAYER LUNGING

2.1.3 User Observation – Activity Mapping

The activity mapping has been based on user observation and 1:1 interview result. This includes observations from tournaments and practices. The main activities are warm-up, playing, breaks, and cool down.

Activity Map

	Arrive at Gym	Warm-up	Playing	Breaks	Cool Down	Return Home
User Goals	• Change into athletic wear • Fill water bottles • Look over their equipment	• Stretch muscles • Participate in training activities • Practice shots and movements	• Moving quickly across the court • Having power behind shots • Shooting to multiple areas of the opponent's side of the court	• Re-hydrating • Quick stretches • Relaxing • Sitting down • Massaging muscles	• Stretch muscles • Yoga exercises • Breathing exercises	• Rest • Have a cool shower • Massage any stiff muscles
Problems/Challenges	• Not wearing the correct apparel	• Not stretching before the game • Training is not focusing on their specific needs	• Not holding the racket correctly • Falling/sliding • Overusing their body	• Having little break time between matches • Not re-hydrating • Not using that time to relax	• Skipping this part	
Key Takeaways	• Players need	• This needs to	• This is when people	• This is the most	• People might	• This helps calm

	breathable clothing and proper shoes	work for multiple people • It needs to be adjustable	will overuse their body • Monitoring will be critical during this part • Highest risk of injury	common time to talk with a coach • This time can vary depending on times allowed	skip this • Similar to training, it must be adjustable • Skipping leads to a greater chance of injury	the muscles down • Injuries will be noticed here or the next day • Depending activities after this injuries, like in the shoulder, are likely to be ignored
Feelings	• Calm • Excited	• Excited	• Highest heart rate • Focusing on the game, not their body	• Tired • Excited for the next game	• Tired • Wants to go home	• Tired • Relaxing • Proud

Table 3 - ACTIVITY MAP

Warm-up: this includes stretching the muscles, participating in training activities, and practicing shots and movement. If a player does not participate in a warm-up, this causes the muscles to be tense while playing which can lead to injury. All activities must be adjustable for each player. The recommended warm-up time is around twenty to thirty minutes.

Playing: this is where a player is put to the test to see if their training has prepared them. Players make quick changes in direction, jump, lungs, and rapidly move their arm (Phomosoupha and Laffave, 2020, pg. 189-99). During play is the highest risk of injury, specifically the ankles, knees, and lower back. Most of these injuries are due to overuse of the body, leaving injuries unknown until they prevent a player from participating.

Breaks: this is between games where a player can rest their muscles and joints. Rehydration is very important to keep the body cool. They can also adjust their equipment if needed.

Cool down: This is after the games have finished and people are leaving. Players tend to stretch again while doing some breathing exercises to relax the body. All equipment is put away and cleaned. If possible due to the location players will have a shower before leaving the gym. Outdoor clothes are put on to prevent damage to badminton specific attire.

2.1.4 User Observation – Human Factors of Existing Products

User Journey Map (Big Picture)

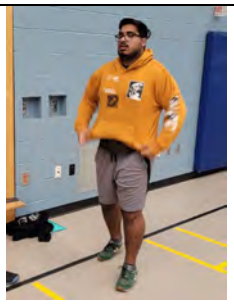
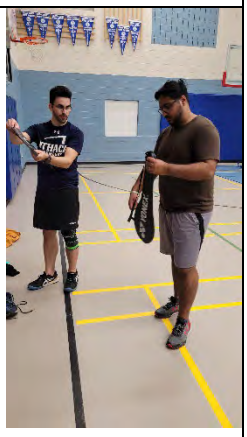
	User Goals	User Actions	User's Thoughts	User's Feelings	Storyboard
Arrive at Gym	Prepare for play	Change into athletic apparel Look over their equipment	I must get ready for training / competition	Calm Excited	

Figure 5 - ARRIVE AT GYM

Warmup	Warm their muscles for matches	Stretch muscles Participate in training Practice shots and movement	Must prepare for matches	Excited	 *Figure 6 - WARMUP*
Talking with Coach	Receive feedback from coach to know how to improve	Absorb the feedback Put feedback to practice	How can I improve my game	Happy Nervous	 *Figure 7 - TALK WITH COACH*

Playing	To win the match	Move quickly Powerful shots Use opponent's weakness to their advantage	I must out play my opponent	Excited Focused	 *Figure 8 - PLAYING*
Breaks	Rest and rehydrate	Re-hydrate Stretching Relax/rest Massage muscles	How can I improve for the next match	Tired Excited	 *Figure 9 - BREAKS*
Playing	To win the match	Move quickly Powerful shots Use opponent's weakness to their advantage	I must out play my opponent	Excited Focused	 *Figure 10 - PLAYING*

Cool Down	Stretch their muscles Let their muscles rest	Stretch muscles Pack up equipment	I am tired and I need to rest	Tired Desire to rest	 *Figure 11 - COOL DOWN*
Return Home	Rest body	Walk / drive home Have hot shower	That was fun, I can't wait till next time	Tired Proud Relaxed	 *Figure 12 - RETURN HOME*

Table 4 - USER JOURNEY MAP 1/2

	Challenges	**Take Aways**	**Emotion** 
Arrive at Gym	Not wearing appropriate apparel	Players need breathable clothing and proper shoes	
Warmup	Not stretching before game Training is not focused on player's needs	This needs to work for multiple people It must be to adjustable to a wide range of body sizes	
Talking with Coach	Not understanding the coach The limited time to speak with the coach	Coach needs to quickly and clearly explain their thinking	

Playing	Overusing the body Falling / sliding Not holding racket correctly	Monitoring performance is critical This is the highest risk of injury	
Breaks	Not re-hydrating Having very little break time Not using this time to rest	This is when the coach speaks to their players There is limited time	
Playing	Overusing the body Falling / sliding Holding the racket incorrectly	Monitoring performance is critical This is the highest risk of injury	
Cool Down	Often skipped Not seen as important	Most people miss this activity It must be more motivating for players to participate	
Return Home		Helps rest the muscles of the body Depending on activities during play, an injury could appear (stiffness or pain)	

Table 5 - USER JOURNEY MAP 2/2

Main pain points related to usability:

- It is difficult for players to focus the game and mitigating the risk of injury
- During play has a higher risk of injury than training/warmups
- Activities to stretch the muscles and prevent injuries are often skipped
- Coaches need a fast and straight forward way to communicate with their players

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The main products used in badminton are the shuttlecock, racket, and net. A shuttlecock, or birdie, is the key part for any badminton game. Most other racket sports hit a ball, squash, and tennis; a shuttlecock however is conical shaped. The shuttlecock is designed to be aerodynamically stable and will always fly cork end first. It is 85-95 mm (3.35"-3.75") in length, 25-28 mm (0.98"-1.1") in diameter at the head, and 58-68 mm (2.28"-2.68") in diameter at the end. The conical shape makes it easier for smash shots, going at faster speeds with less drag. For a badminton racket, the mesh oval is 220-230 mm (8.66"-9.06") in width with the handle is 25.4 mm (1") in diameter. Overall, the racket is 665-680 mm (26.18"-26.77") long. Once the match starts rackets move in various ways to strike the shuttlecock and continue the game. It is lightweight, although some players will take a heavier racket to put more power behind their shots. Regardless, it acts as an extension of the player's arm being moved quickly and slowly. The net must be 6.1 meters (20 feet) long and 0.79 meters tall. It must be 0.76 meters (2'5") high off the ground. The net is about the same height as the shoulder, this helps in judging net versus smash shots. All these elements are important for a good badminton game.

Figure 13 - RACKET & SHUTTLECOCKS

2.1.5 User Observation – Safety and Health of Existing Products

There are very few products that monitor player movement. The only ones are smartwatches and phones to record plays. Most benchmarked products do not encounter the body, only training equipment does. There is a slight risk of pulling a muscle or falling with equipment like minibands and a balance pad. But those risks are required to improve one's ability to increase their stamina, speed, and power. They help build muscles in the legs, ankles, shoulders, and wrists. These help to prevent injury by increasing the response time of different parts of the body.

2.2 Product Research

There are very few products on the market for monitoring the movement of badminton players. Most products on the market focus on medical monitoring, coach assistance, and training equipment. The use of these products depends on the player and coach as some provide more benefit than others. Here is where we will explore how these products help the player and coach improve overall performance.

2.2.1 Benchmarking – Benefits and Features of Existing Products

The products most used are smartwatches, equipment accessories, coaching software, and training equipment. Smartwatches are the most popular as almost everyone wears one, whether it is an Apple smartwatch or Fitbit. They monitor heart rate, calories burned, etc; this information is useful for a player and the medical team. Equipment accessories like Usense are attached to a player's racket to monitor the speed of their swings. To access this information the player can open the Usense app on their phone. Coaching software like Dartfish can do video analysis, view slow-motion, and draw on video all from an app. With training equipment, it helps build muscle and prevent injury by focusing on different parts of the body. Common training tools for badminton are minibands, balance pads, and kettle bells. While these products do have benefits, sadly few of them can send information during play.

2.2.2 Benchmarking – Functionality of Existing Products

These products do provide benefits to the players and coaches; however, some are more functional. Out of all the products listed, training equipment provides the biggest benefits as it has been perfected over the years. For badminton they know what muscles need more attention and how to train them. Technology on the other hand, is still new and can improve over time. The inconvenience that these products have is that you can only see the information after a game. This prevents a player from being able to adjust during a match. Newer training equipment is coming out that is

badminton specific, like the SD200 Shadow Trainer by Black Knight. It helps with shadow training, getting the player to move to all areas of the court in random variations. The best training includes the most realistic experience. Coaching software provides different experiences, and some are easier to use than others. They provide the ease of having all sports-related videos and contacts in the same space. However, the records only provide visual information that the player or coach can see. Equipment accessories provide a deeper understanding of what happens during play. Although, it is inconvenient to have to check an app every time you want to know how your play is going. The best functionality is easy to access, provides a lot of information, and doesn't interfere with a player's game.

2.2.3 Benchmarking – Aesthetics and Semantic Profile of Existing Products

These products vary in purpose, design, and functionality making the aesthetics extremely different. Physical products like training equipment and equipment accessories are focused on safety. Ranging in colours, their forms are simple using basic shapes to communicate their purpose. Any area that requires physical contact tends to be a different colour and texture from the rest of the body. For example, a balance board has a rough texture where the feet will be and a rubbery texture where it touches the floor. There are little to no graphics on these products aside from branding. Most finishes are matte to provide better grip and keep them looking cleaner longer. The main material is plastic and rubber, some also include metal. The technical products, smartwatches, and coaching software do not have the same requirements as the physical products. For the physical part of a smartwatch, they have a variety of options, if it is more sports based then it has a similar aesthetic. As both these products connect to apps the aesthetics are up to the companies. Layouts are designed to have important information to standout, which is controlled by the user. Regarding color, dark mode is becoming more popular as it is easier on the user's eyes. The style is minimalist and simple while still providing easy access to any tools provided within the app.

All these products have a similar personality and expression, they want to benefit their user. When one looks at these products it recalls motivation, determination, and a drive for improvement. Whether it is training equipment that prepares the player before the game, or coaching software that is used for reflection. These are all important to improve the skills necessary to do well in a sport. The main emotions drawn from these products are happiness and surprise, the same emotions one gets from sports. These are the same emotions that motivate an athlete to improve their skills and a desire to win. Badminton players are more familiar with training equipment than any other products that has been benchmarked. They have been used since the beginning of the sport; technical products have only recently been used. Smartwatches are becoming more common, although their information is not always the most beneficial. Coaching software is not overly used as they tend to require subscriptions and do the same things as the average smartphone. One problem is that no technology is allowed during a competition, preventing the use of smartphones and watches. Technology only helps the players during the training process, preparing them for what they will face during a competition.

2.2.4 Benchmarking – Materials and Manufacturing of Existing Products

This section looks at products currently on the market in relation to badminton and how Step Up could be different. It specifically investigates the materials and manufacturing processes used and how Step Up can be manufactured. The goal is to not only have Step Up benefit the user, but also the environment. This will investigate how to provide the best benefit while also in both material choices and manufacturing processes. With the hope of designing a more sustainable system of products.

The benchmarking of materials used in fitness products will be displayed in the chart below. This focuses on the benefits, disadvantages, and applications of these materials.

Material Options

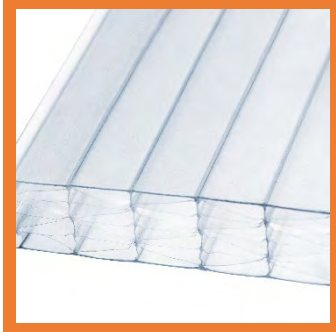
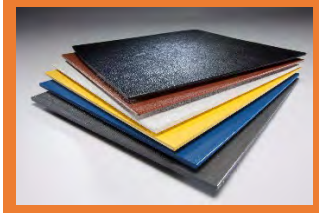
Material	Benefits	Disadvantages	Applications
Polycarbonate:  *Figure 14 - POLYCARBONATE*	It is the most common plastic due to its: • Strength • Appearance • Transparency • Heat resistance • Ability to blend with other plastics	It is rare to find pure polycarbonate in any products due to how expensive it is. It will be combined with other plastics to lower total costs and increase benefits.	• Lens • Water bottles • Lighting components • Sporting goods • Medical products and components
Polycarbonate and ABS:  *Figure 15 - POLYCARBONATE & ABS*	This is one of the most common pairings for polycarbonate. When combined they provide: • A good appearance • Mechanical resistance • Chemical resistance • Easy to process • Flame retardant • Weatherable grade available • Lightweight • Malleable • Ductility	The biggest disadvantage is that it isn't UV resistant	• Business machines • Automotive components • Small appliances • Portable electronics • Medical components
Polycarbonate and Polyester:	This is common for sporting goods due to its:	The main disadvantage is that it is	• Automotive components

 *Figure 16 - POLYCARBONATE & POLYESTER*	• Strength • Chemical resistance • Painting ability	difficult to mold.	• Lawn and garden • Medical products • Sporting goods

Table 6 - MATERIAL LIST

Material	Manufacture Process
Polycarbonate	Injection Molded: 1. Clamping 2. Injection 3. Dwelling 4. Cooling 5. Open mold 6. Eject material
ABS	1. Clamping 2. Injection 3. Dwelling 4. Cooling 5. Open mold
Polyester	Spinning: 1. Create a monomer 2. Turn that into a polymer (multiple times) 3. Extrude 4. Spinning cycle (multiple times) 5. Finishing

Table 7 - MATERIAL & MANUFACTURE

2.2.5 Benchmarking – Sustainability of Existing Products

Most of the existing products either monitor a player or train a player. Regarding monitoring, that is mostly coaching software which one can download onto a phone. However, most of the products are made of plastic using

injection molding. For the training products, the sustainability aspects depend on the brand. Training equipment like minibands or a balance pad are made using a mixture of hard and soft plastics. Often made using plastic or rubber to get the necessary grip for users. There are more sustainable options, for example, recycled plastic is often used in place of new plastic. Natural rubber, cork, and organic cotton are used to replace plastic in equipment. For products like a balance pad, bamboo or wood is used. Even though these materials are sustainable it also depends on where and how they are found. Products that are made using sustainable materials also tend to be more expensive.

2.3 Summary of Chapter 2

To summarize this section, the main problem is to monitor the physical performance of a player. Focusing on this from both the player and coach's point of view. Badminton is available to anyone and is relatively inexpensive. Most players tend to be between their late teens to forties, but injuries are more common for those in their twenties. The main activities are warm-ups, game play, breaks, and cool downs. All one needs to play badminton is a shuttlecock, racket, and a net. Stretching before and after game play is the most common way to prevent injuries to the body. Few products on the market monitor player performance, those that do only focus on medical information. Training equipment provides the most benefit by preparing the body before a game, most are only beneficial afterwards. The functionality of the training products is good as they focus on different parts of the body. Coaching software on the other hand, does the same as the average smartphone. The aesthetics are minimalist and simplistic, mostly made of plastics with a variety of textures for the safety of the user. Emotions that these products give off are motivation, desire to improve, and determination.

CHAPTER 3 ANALYSIS

3.1 ANALYSIS - NEEDS

This section investigates what is currently missing and how the badminton experience can be improved for players and coaches alike. Are all their needs met, if not how can that be improved. What takes priority for every stage in the sport, from training to a competition. How can the sport be taken ten years into the future to benefit play on both the recreational and professional level. What ergonomics will come into play and how will that change the product.

3.1.1 Needs/ Benefits Not Met by Current Products

The main need is to be able to monitor one's performance to track improvement and prevent injury. There is nothing on the market that can track movement, technical skills, or force. Certain tools like coaching software assist the coach but is only able to scratch the surface. Players need something that looks deeper behind their movements and informs them of how they can improve. Specifically focusing on training, as technology is not allowed during tournaments. It is training equipment that provides the most benefit for the body before a game. Products like smartwatches and coaching software are only helpful after a game, at which point there might already be an injury. Products that do monitor movement only focus on one part of the body and require an app. Like smartwatches and coaching software, this information is only helpful after a game. Players need a product that can monitor the body and for their coach to receive live information.

3.1.2 Latent Needs

The latent needs of the badminton player are to stay healthy, physically fit, and have more practice time. To do this they must be able to monitor their movements and performance. At this point, they can only rely on what their coach sees and how they feel. This is not the most reliable as the desire to improve and have fun can push logic aside. Often

leading to injuries and a misuse of limited practice time. The best way to monitor a player is during training when technology is allowed, and adjustments can be made. This product will be worn by the player and monitor their physical movement focusing on high-risk areas. It is lightweight and breathable so as not to interfere with the player's performance. Information like speed, flow of movement, force, and technic will be recorded by the product. This information will be sent to the coach and receive live feedback so play can be stopped if needed. That way the coach can adjust training to focus on important areas and have a deeper look at how the player reacts. The player also has access to this information to make their own adjustments, especially if they feel they are at risk of injury. This benefits the medical team at tournaments by knowing what happened right before a player was injured. As well as if the player has any past injuries which could interfere with their game. This allows a player to monitor their own health, with their coach and a medical team able to monitor it as well. That helps a player to stay physically fit by having a deeper understanding of their body. Training can be more direct in specific areas, so the limited time is used to its full potential.

3.1.3 Categorization of Needs

Latent Needs	Immediate Needs	Wants	Wishes
Stay Healthy	Focus Specifically on Footwork	Multi-functional Braces	Less Expensive Equipment
Stay Physically Fit	Communication (in Doubles)	Access to a Professional Court	Easily Carry All Equipment in One Bag
More Practice Time	Developing Technic		
	Maintain Equipment		

Figure 17 - CATEGORIZATION OF NEEDS

3.2 Analysis - Usability

To design a product to best fit the needs of a badminton player is to observe their overall emotional experience. This focuses on the positives and negatives that they go through from when they entre the gym to when they leave. The

purpose of this is to better understand how a player feels while playing badminton. This will help lead to a product that increases the positive emotions and limits the negative ones.

3.2.1 Journey Mapping

Figure 18 - ENTERING THE GYM

Entering the Gym

When a player enters the gym they carry their equipment and a water bottle. They tend to feel excited and calm at the same time, looking forward to a fun game. Players will prepare for warm up by putting on the appropriate footwear and clothing. For proper equipment care, players will also look over their own rackets and shoes. The team will use this time to catch up and talk about their game plan with their partner.

Figure 19 - TALKING WITH COACH

Talk with Coach

In tournaments players will talk with their coach for any last advice before the game starts. During a tournament multiple games can be going on at the same time, making this time limited. Coaches focus on the most important information before moving on to the next player or team. This time tends to be stressful for both player and coach.

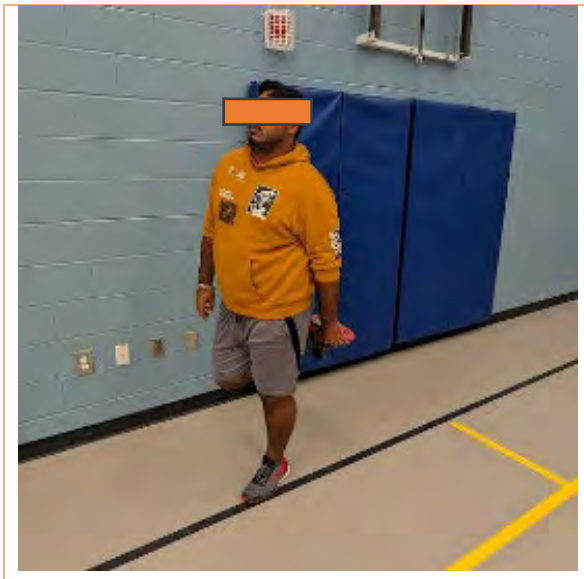


Figure 20 - WARMUP

Warm Up

After speaking with the coach, players will use this time to stretch, participate in training drills, and practice with a partner. It is important to stretch the ankles, knees, hips, and shoulders before starting a game. The main training drills used are footwork drills, shadow drills, smash practice, and net play drills. These drills help a player improve their overall stamina, speed, and power. If there is not a lot of time before a game or if it is just recreational, players will play quick games between each other. This is where they do not have a desire to win, but to warm up their muscles. It also builds hand-eye coordination and communication between partners. This is where players focus their mind and calm themselves before the games begin.

Figure 21 - PLAYING

Playing

Once the matches begin players must move quickly across the court and twist their bodies in odd ways to prevent the shuttlecock from hitting the ground. This has the highest chance of injury throughout the entire experience of a badminton player. They can become so focused on the game that they don't pay attention to how they are moving. This is where a player's stamina is very important to prevent injury. It is rushing from one side of the court to the other where ankles become twisted and unaligned with the rest of the leg. Players will dive for net shots which can lead to them landing on their chest or knees. Smash shots often cause overuse of the shoulder. Even though this tends to be the most exciting time for players it also has the highest chance of injury.

Figure 22 - BREAKS

Breaks

This is between matches where players will rehydrate and rest their bodies. Coaches have an opportunity to speak to the players and give feedback before the next game starts. Players will massage their muscles at this time if they are feeling overly sore in a certain area of their body. In tournaments medical teams may check on players if they feel they might be injured. Players start to become tired at this time, while still looking forward to the next game. They might notice stiffness or pain at this point. Unless it is severe pain, players tend to play through the pain.

Figure 23 - COOL DOWN

Cool Down

This is once all the games are done, and the tournament is over. Teams will have a talk with their coach for any last feedback for their next meeting. Calming stretches will be done at this time to relieve any tension build up in their muscles. Some players will skip this part which has a greater chance of injury. After the stretching is done players will pack up their equipment and head home. At this point they tend to be very tired and either happy or disappointed depending on how their games went.

 *Figure 24 - LEAVING GYM*	Leaving the Gym Once the players leave the gym they go home and relax. This can depend on the individual, but they will often have a shower and rest. Feeling content and happy.

Table 8 - JOURNEY MAP

Possible Areas of Improvement

Entering the Gym:

- Responsible for a lot of equipment.
- Need to bring in multiple shuttlecocks, nets, and poles.
- Provide an easier method for moving all this equipment.
- Breathable equipment.
- Bag to hold everything.

Talk with the Coach:

- Including medical history.
- Provide a list of advice beforehand.
- Include visuals to quickly explain.

Warm Up:

- Have access to monitoring equipment.
- Use training equipment.
- Automatic referee to track the movement of a player.
- Specialized court and equipment.
- Automatic trainer.

Play:

- Cameras to monitor multiple games at a time.

Break:

- Quick review of previous game.
- Bands the heat and relax certain muscles.

- Automatic massager.

Cool Down:

- Smart yoga mat that tracks the stretching of a user.
- Massager to relax muscles.

Leaving the Gym:

- Bag to hold everything.

3.2.2 User Experience

To analyze the journey mapping data of a badminton player, a visual representation was created. Regardless of whether it is for a tournament or regular training the steps are the same. This is to find the main pain points of the player. The chart below shows what the players' goals are, any challenges they could face, my takeaways, and the players' feelings. This is to get a deeper understanding of what is going through the player's head. It is a tool to recognize key areas that will adjust the proposed design solution.

In this graph it explains the process a player goes through when going to play badminton.

	Arrive at Gym	Warm-up	Talking to Coach	Playing	Breaks	Cool Down	Return Home
User Goals	Prepare for playing	Warm their muscles for ease of movement while playing	Receive feedback from coach on how to improve	To keep the shuttlecock from landing on their court	Rest their body and rehydrate	Stretching and cooling their muscles	Rest their body
Problems/ Challenges	Not wearing the correct apparel	Not stretching Training not specific toward individual's needs	Not understanding coach Limited time frame	Falling / sliding Overusing their body Can lead to injury	Having limited time Not rehydrating Not resting	Often skipped Not taken seriously Can lead to injury	Ignore any slight pains Leave injuries unchecked
Ideas/ Takeaways	Player needs breathable	Solution must be multi-functional	Provide a way to quickly /	Highest risk of injury	Will often receive feedback	People might skip this part	Helps calm the muscles

	clothing and footwear	Needs to be adjustable	clearly explain their thinking	Monitor movement is critical		Injuries go unnoticed	Risk of injuries being ignored
Feelings							
							
							
							
							
							

Table 9 - USER EXPERIENCE

This shows that players are most excited when getting ready to play and while playing. However, this is also when they are most at risk of being injured. A player tends to focus more on the game than their body, which leads to overuse injuries. A coach will watch their players but cannot focus on everyone all the time. The main takeaway is that there must be a way to monitor a player during play, specifically their physical movement. It must allow players and coaches to review the information recorded and make any necessary adjustments. As shown in the graph, players tend to notice injuries after they have occurred. The goal is to prevent those injuries before they happen, this turns to training the body through using proper technic. A player must be able to monitor their improvement even if a coach is not present.

3.3 Analysis – Human Factors

Badminton players, like most athletes, focus more on the game than their body. This leads to overusing the muscles in their body which then causes injury. Players vary greatly in size and so the equipment they use must fit their needs. Their apparel must come in multiple sizes and comfortably fit any player while still providing freedom of movement. The fabric must be lightweight, stretching, and breathable to prevent the player from overheating. Rackets must be specifically chosen by the player to best fit their needs. Some prefer heavier rackets to lightweight ones as the extra weight can add more power to smash shots. Footwear is important for players in providing the necessary traction on the court floor. Some players will wear braces, they must provide support while not preventing a player from moving. All these products must work together to best assist the player in their match.

Before the ergonomic study was conducted, literature was reviewed to provide insight into how the body moves. Information regarding specific joint locations and hand measurements was received from Henry Dreyfuss "*The Measure of Man and Woman*", it is also the main source for measurements. This is to make sure that all products within this system fit well with the body for best use. It provides the exact measurements for where joints are for the 95th male percentile and 5th female percentile. This will allow for the sensors to monitor these areas with utmost accuracy. Of course, all this had to be tested to provide the best experience for the user. To conduct this study a schematic layout was created to pinpoint the location of all main elements of the products. One-to-one scale mock-ups were built to test human ergonomics with the two percentiles. The goal was to learn the level of difficulty a user had learning how to use the products and overall user experience.

Decisions to be Made:

This study provides a deeper understanding of the interactions of major body parts with the current designs. It will shed light on what needs to be adjusted to improve the final design. These include:

- Location of joint sensors
- Range of motion for material
- Camera size
- Flexibility of fabric to suit movement

3.3.1 Product Schematic - Configuration

User Targeted by Study:

Badminton players and coaches between 20 and 40 years old that are at intermediate level or above. There are no height or size limitations for players, which means these products must fit a wide range of body types. The suit will come in multiple sizes, but the camera and racket will be fixed dimensions.

Evaluation Process:

The one-to-one models were created using Adobe Illustrator to get a fair comparison in size differences. Having them side by side showed a large difference in joint height and hand size differences.

Results:

Ergonomic Diagrams:

The figures in this diagram show both the 95th male percentile and 5th female percentile. This is for testing how the entire body will interact with the multiple products in this project. They include all the main measurements such as overall height, joint heights, width of the chest and, and width of the hips. These measurements will inform and improve the final designs for this project.

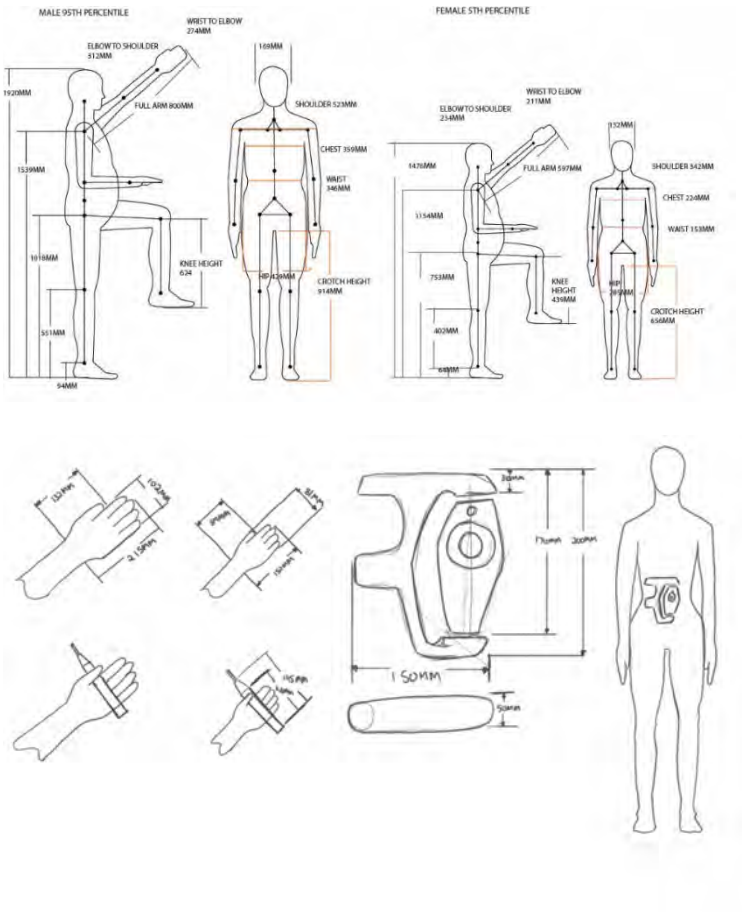


Figure 25 - MEASUREMENTS

The above diagrams show the necessary measurements for the products to comfortably both the 95th and 5th percentile people. This includes the necessary measurements for the racket handle so the player can have a firm grip while playing. It shows the maximum dimensions that can be used for the camera. These measurements are to make sure the user can easily hold the camera while attaching it to the net post. It also includes the diameter of the net post for and

comfortable and secure fit. The suit must be skintight, so these sketches show the location of the joints, which is why side views are included.

3.3.2 Ergonomic – 1:1 Human Scale Study

The one-to-one testing was conducted with volunteers that had the same dimensions as the 95th percentile and 5th percentile. The goal was to test the overall comfort and mobility of the user to find any problem areas. More design refinements would be decided during this section of the design process to improve the final products.

Figure 26 - ERGONOMIC TEST FOR MALE

Figure 27 - ERGONOMIC TEST FOR FEMALE

The above figures are the 95th male percentile and 5th female percentile wearing a one-on-one mockup of the tracking suit. White markers were placed on all the main joints, one on the lower section of the stomach aligned with the hips, and one in the centre of the chest to act as the main marker. Orange stitching was used to show how the sensors would all be connected. The volunteers posed in certain ways they are common positions to be in while playing badminton. They were able to freely move around with the markers staying locked beside their joints.

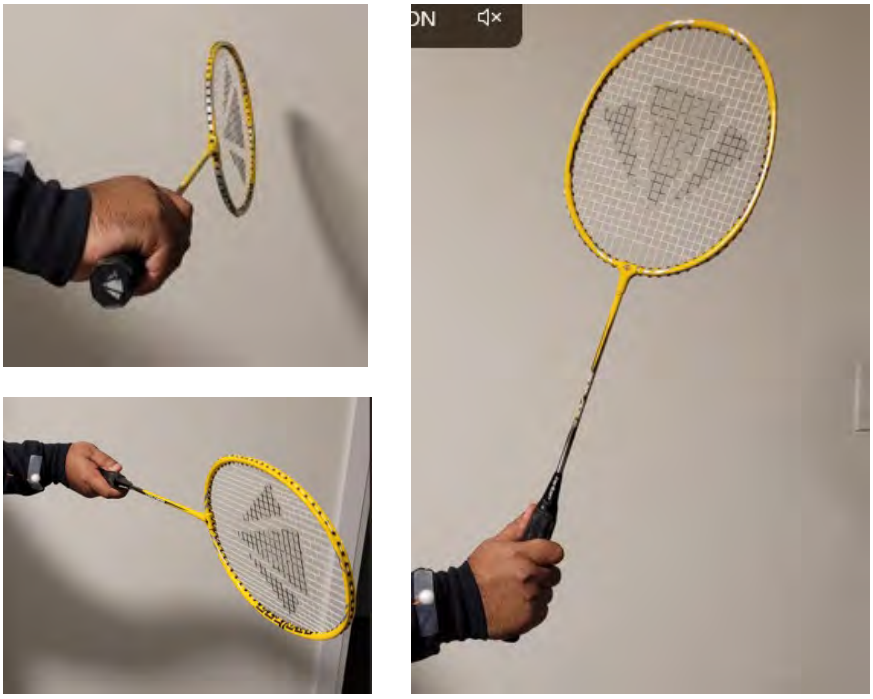


Figure 28 - ERGONOMIC TEST FOR RACKET

The figures above show multiple positions that badminton rackets are often held in. This shows they must be comfortable and aerodynamic to flow with the player's movements. It will have grip sensors underneath the strap for the handle. There must be enough gaps so the sensors can read the amount of pressure of the handle while not interfering with the play.

Figure 29 - ERGONOMIC TEST FOR CAMERA

These figures show the size of the camera compared to the 95th male percentile's hands. Those are the common ways to hold the camera while installing it on to a badminton net post. This shows that it is unclear to the use how to properly hold the camera, this will have to be adjusted in the final design.

Analysis:

After conducting the study, many areas and touchpoints were analyzed to see if the dimensions would have to be adjusted to better fit the ergonomics of the two percentiles. The analysis showed that certain areas would need further consideration to comfortably work with a variety of users.

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Observation 1:

The sensors are in different locations depending on the size of the body. This difference is too great to make one size to fit all. It will need to come in a variety of sizes.

Observation 2:

The suit must be skintight to have the most accurate tracking of movement. As shown in figures 4 to 12 the mockup was too loose for both the 95th and 5th percentiles. Stretchable and form fitting materials must be used.

Observation 3:

The camera, while able to rotate, is unable to cover an entire court. Rotating vertically works well, but the arm would have the camera too close to the post for horizontal rotation. The camera must be moved out 2 inches from the post or another rotation method must be investigated.

Observation 4:

The badminton racket handle allows for easy movement so the player can hit a variety of shots. As seen in figures 13 to 15, it must be easily held in any position.

Observation 5:

The stitching must not interfere with the player's movement and the fabric must be breathable. Figures 4 to 12 show that the fabric used in the mockups would be too thick and cause the player to overheat. This must be adjusted for when the final model is built.

Limitations

One limitation is if the user is over the size of a 95th percentile male there is a high risk of both the suit and racket handle not working correctly. Not only would it be difficult for a user to fit into the suit, but the sensors would not line up correctly with the joints. This would make any data collected faulty. As for the badminton racket handle, if the user's hand is too large it would be uncomfortable to hold. These points must be taken into consideration as the designs move forward.

Another limitation is the overall shape of the camera. The dimensions work well with both percentiles, but the shape is uncomfortable and unclear of where to hold it. Both the shape of the camera and arm to attach to the post will have to be adjusted. It will need further testing so the camera is easy to install and can rotate 360 degrees.

Conclusion

This study has shown how some designs will need to be altered, however there are still some ergonomic issues that are still not yet resolved. It was not possible to test certain types of fabric for the suit. This makes it difficult to know if the suit sensors would be comfortable and allow the user to move freely. Online sources will be able to recommend fabrics that fit the necessary criteria, for example nylon. This study has helped to identify challenges while wearing the tracking suit, badminton racket handle, and installation of the camera. It shows the ability for the sensors to stay with certain joints while in motion. The racket handle works well but the sensors must be able to work regardless of how the

handle is being held. However, the camera design does need to be altered slightly to allow for full rotation and easy attachment to a net pole. Overall, this study showed that this system of products connects well with the three-specific major body-part areas. These results will help adjust the design to improve the ergonomics and provide a comfortable experience for the user.

3.4 Analysis – Aesthetics & Semantic Profile

This is considering the needs of an athlete in a fast-paced game such as badminton. The design uses futuristic sports trends and then pushes them even further into the future. It is inspired by the human body and complements the natural curves of it while also incorporating similar shapes as seen in badminton.

The suit focuses on following the curves of the body but using dynamic lines to show strength. This will be shown in the stitching pattern to connect the sensors and in the areas where mesh will be. The mesh allows more air to the skin to help keep the player cool during practice. Dynamic lines are being used because they relate to a stronger frame, like the skeleton of a building. They will draw attention to certain sections of the body, specifically the thighs and shoulders which are used a lot in badminton.

The badminton racket handle and tracking camera will have organic and aerodynamic shapes in the body. However, dynamic lines will be used to draw attention to certain aspects and to make all three products look cohesive. Both the handle and camera must be aerodynamic to move with the player and prevent as much drag as possible. The following inspiration board was created to help explain the aesthetics and semantic profile that will be used in this project.

Figure 30 - INSPIRATION BOARD

3.5 Analysis – Sustainability: Safety, Health, and Environment

As we move forward more products are becoming more sustainable to battle global warming. That is no different for the sports industry, which is why both sustainability and physical fitness must be promoted in unison. Not only is this suit and camera training system designed to help the body, but it is also designed to be sustainable. The materials for the suit are harvested from sustainable sources that only use natural pesticides. Only natural dyes are used, and any chemicals will be removed during the wash phase of manufacturing. The polycarbonate, ABS, polyester, and rubber for the camera will all be recycled. Low-heat 3D printing will be used for any components containing ABS. All these components were chosen not only to have a more sustainable product but also to have a long-life span. It will also help the user by having a protective layer of fabric for sensitive skin and using eco-friendly manufacturing methods. This will bring more attention to sustainable farms and forests to promote a sustainable way of life.

3.5.1 Safety

Research has shown there is a wide range of materials that can be used in sports gear and equipment. Badminton rackets use horsehair to manufacture their strings and shuttlecocks use real bird feathers. The only issue with

this is that they are less durable than synthetic products. Feathered shuttlecocks break apart easily, which is why they are only used during competitions. That is why for Step Up if there is no organic solution for durability, there is a recycled solution. The sensors will be made of recycled polycarbonate and polyester due to their toughness and chemical resistance. This will protect the accelerometer and heart rate monitor inside the sensors. A steel skeleton covered with a sleeve of recycled rubber is used to attach the camera to the net post. The body of the camera is made of polycarbonate and polyester with an outer shell in recycled rubber. There is a polycarbonate shield to protect the lens of the camera. This will protect the camera and provide a tight grip surface to prevent damage. These measures will ensure a long life for these products.

3.5.2 Health

The health of a player is important in any sport, which is the reason all equipment is designed to protect the player. Overheating and lack of mobility in products are some of the biggest problems in sports. Athletes have risked their own health to prevent any interference with their play. Special materials have been chosen for Step Up to allow full movement and airflow for the player. There are multiple areas of the suit that are mesh, specifically the armpits, back of the knees, and back. This allows for more airflow and ease of movement to prevent injury. As there are electrical currents that will be moving throughout sections of the suit an organic cotton layer has been added. This will protect the skin as it is soft and delict. Organic cotton is also chemical free as only natural pesticides are used on sustainable farms. This will protect the player and not interfere with their play.

3.5.3 Environment

Sustainability and its effect on the environment are becoming popular in the sports industry. Sports get worldwide attention, whether it is for a recreational game or the Olympics. It is the best way to introduce sustainability to the world by showing there are better methods that don't affect the environment. The 2019 Helsinki International Horse Show used

electricity generated from horse manure to power the indoor sporting event. The Johan Cruijff stadium in Amsterdam replaced 53,000 seats with ones made of 100% recycled plastic. It is great that more sustainable ways are being used, but it can be taken further than just where the athletes play. By using model fabric and organic cotton in the suit it has little effect on the environment and promotes sustainable farming. Using recycled plastics in the body of the camera helps prevent more chemicals being released into the atmosphere. Natural rubber in the outer shell of the camera not only helps the environment but protects the camera from damage. There are so many ways that sustainability can be brought into the sports industry, we are just beginning.

3.6 Analysis – Innovation Opportunity

Being able to track players in a sport is very rare, and similar tracking systems are used to follow the game. People do not focus as much on the actual players, this needs to change so athletes do not become severely injured. This puts the power of monitoring into a player's own hand. The goal of any athlete is to improve and to optimize physical activity. But attention falls into focusing only on the game itself, where players find it difficult to monitor their improvement. Even for a coach this is difficult, especially when players play doubles. However, this system of products will allow players to focus on the game and be able to review themselves afterward. This will provide a deeper understanding of how the body moves. A player and their coach can use this knowledge to adjust training and track progress. That way more attention can be paid to the game, with less distractions.

3.6.1 Needs Analysis Diagram

To best assist both badminton players and their coaches this solution must work with their ergonomics and be easily accessible. Focusing on immediate needs which are optimizing physical fitness and mitigating the risk of injury. To

do this the suit and camera must be able to create and record a virtual skeleton of the player. This will allow the player to have a deeper understanding of how their body moves. It will show which areas need to be focused on for improvement and which areas could be at risk of injury. Of course, to truly benefit the player and coach this system must fill more than just their immediate needs. Below is a table that includes latent needs, wants, and wishes of players and coaches.

Needs Analysis

Immediate Needs	Latent Needs	Wants	Wishes
• Better understanding of the body • Mitigating the risk of injury • Personalized training drills • Increased stamina, speed, and power	• Monitoring high risk areas of injury • Tracking overall health • Products to work well in any environment • Social belonging to a team • Mitigate fear of losing • Motivation for self-improvement • Social recognition	• To be at the best • To improve their skills in badminton • Play to their full potential • To monitor their improvement • To receive quick clear feedback	• For there to be no risk of injury • For equipment to be less expensive

Table 10 - NEEDS ANALYSIS

One latent need that is often overlooked is the social belonging of a person. In this case, as an athlete, if they cannot continue to improve, they will be cut from the team. This is one of the biggest motivators for both players and coaches alike. Which is why this system must provide them with the necessary information to improve, but from there it is up to the individual. This works closely with the immediate need to understand the body.

Another latent need is to be environmentally friendly, which goes for all sports. For badminton, all tournaments use feathered shuttlecocks and some strings for the racket use horsehair. This shows that there are some sustainable elements in badminton already, but it can be taken further. For the sensors to connect copper stitching has been chosen as it contains less technology. That way at the end of the product's life it can be easily recycled. Another option was nanotechnology, but that would surround the entire suit and be impossible to separate. Because the suit's main material will be nylon it will fade and weaken over time. This will also make the system less expensive, which is a wish for players.

3.6.2 Desirability, Feasibility & Viability

Badminton is a well-known and beloved sport, whether played professionally or recreationally. regardless of the level of a player, there will always be a drive to improve one's skills in badminton. It is human nature to improve and a drive for competition. Being the best version of oneself has aways been a latent need of people. This need is stronger in sports, as there is always one available regardless of age, overall fitness, financial situations, or time availability. It provides the feeling of community and personal growth that brings joy to people.

There is a large market gap in tracking the movements of players. The only tracking technology used in sports is hockey, where cameras can track the hockey puck. This is due to sensors in the puck and the contrast between the black hockey puck and the white ice. Tracking players can provide a greater benefit during training sessions. The information provided will help coaches to adjust training to an individual for their specific needs. It allows coaches to get feedback from multiple games, even if they are unable to watch all of them. Most technology is only focused on following the game over the player, tracking the movement of the puck, ball, or otherwise. But those objects will not improve the score or win the game. It is up to the players to increase their skills and their drive to compete, so shouldn't we be focusing on them.

3.7 Summary of Chapter 3 – Defining Design Brief

After the analysis was conducted, focusing on user needs, usability, and aesthetics, a design brief was made. The purpose of this design brief was to create specific guidelines so the final design can provide the strongest benefits to the user. For this thesis the focus is on monitoring the physical performance of a badminton player. This information will help both players and coaches track improvement and mitigate the risk of injury. The design brief will continue to develop throughout the design process.

Thesis Design Brief

The goal of this thesis project is to provide a deeper understanding of how the body moves in badminton. This will help players and coaches understand how to optimize their physical fitness and mitigate the risk of injury. Allowing changes in training to focus on an individual's needs for improvement of their badminton skills.

Design Brief

Needs	A player's basic need is to optimize their physical fitness. Their coach must be able to help a player make that a reality. To do this both must have a deeper understanding of how the body moves. This connects with the need to mitigate the risk of injury. If a player becomes injured, they will not be allowed to participate in games. The solution must be able to monitor a player's movement and then communicate that data to the player and their coach.
Usability	For usability training happens during the warmup and a player will then discuss improvements with their coach. Practice games within the team is the best time to monitor improvement as the player is not focusing on their body. However, this is the busiest time for a coach as multiple games are going on at the same time. During breaks is the only time during games that a player can receive feedback, but this time is very limited. The solution must be

	able to monitor the movement of a player so they can focus on the game. This information must be recorded so a coach can review it later. During play is the best time to observe a player to track improvement but is extremely difficult to do so.
Human Factors	The human factors analysis showed where the main joints are for both the 95th male percentile and 5th female percentile. This showed that the best way to monitor the physical performance of a player is to have a wearable suit. That means sensors would have to be skintight on the player's body. The measurements provided by *Henry Dreyfuss "The Measure of Man and Woman"* is important to receive the most accurate data. To record this data a camera is required, so it must be easy to install and comfortable to hold. Another thing that needs to be recorded is the location of the badminton racket. This data will help with shot training, specifically smash shots, and net shots. This will be tracked using sensors in the handle of the racket. The hand measurements of both percentiles will be needed to make a player have a firm grip on the racket.
Aesthetics & Semantics	As part of the solution is a wearable it will need to follow and surpass current fashion trends. The fabric needs to be stretchable and breathable. There will be copper stitching used to connect the sensors, so they will have to be protected in a way so the suit can be washable. The suit will be made in a way to complement the natural curves of the body while using dynamic lines to create a sense of power. The camera and racket handle will also need to complement the body. This will make all three products look like a cohesive family.
Sustainability	The suit, sensors, and camera will be made of sustainable materials. Both the model fabric and organic cotton will be harvested from chemical free farms. The manufacturing process for both fabrics removes any remaining chemicals. Materials for the camera are all natural or recycled, to prevent the spread of pollutants into the air. Giving these products a long-life while still providing the user the best experience.

Innovation Opportunity	This has never been done in sports up to this level. It will help drive the motivation players have to optimize their physical performance. The goal is to not only help the player improve, but also mitigate the risk of injury. One day hopefully this kind of technology can be used in all sports.

Table 11 - DESIGN BRIEF

The goal of this thesis is to monitor the physical performance of badminton players. Which will help track the improvement of players and mitigate the risk of injury. This is done by having the player wear a tracking suit with sensors in the badminton racket handle and having a camera follow them around the court. Both the suit and the camera follow movements of the joints to create a virtual skeleton. Those movements are then recorded and monitored to track high risk areas of injury. This data is then recorded to future review and to track improvement. The racket sensors track grip and movement which focuses specifically on shot training. These products together create a family that will help players and coaches in their badminton journey.

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CHAPTER 4 DESIGN DEVELOPMENT

4.1 INITIAL IDEA GENERATION

After the basic research was completed, the design process could begin. This creates a path on how to best fulfill the needs of both badminton player and coach. A mind map was created focusing on the users, products, and the environment. This helped to plant the basic form of the product designs so they could develop. It was important that all these products could stand out both individually and as a system. The aesthetics are critical for fulfilling the impression players want to give off, a sense of stamina, speed, and power. The first ideations focused on which areas were the most important. This leads the entire project to continue to develop and become the final system.

4.1.1 Aesthetics Approach & Semantic Profile

Figure 31 – AESTHETICS APPROACH & SEMANTIC PROFILE

The inspiration board was created to provide insight into the overall form and stylizing of the three products. This was used to generate new ideas and take the designs into the future. Things like other tracking cameras are used to see how the different forms connect and possible rotation points. Bats, cars, and a hockey team logo are used to see a

variety of how colours and dynamic lines can still complement an organic form. They are then used to push the designs forward.

4.1.2 Mind Mapping

A mind map was developed to better understand the target audience and what their preferences are based on their environment and what is already on the market. The teal rectangles separate the user, products, and environment of use. These products are focused on benefiting the badminton player and their coach. A variety of products are available, some provide more benefits than others. The products are the purple squares, the most noticeable thing is that no product currently on the market truly tracks a player's movement or dives as deep as this project plans to. Not much information was needed to understand the environment as badminton is played indoors. The dark green rectangle is a layout of the court. This was important to know how to track the player and what range the camera would need.

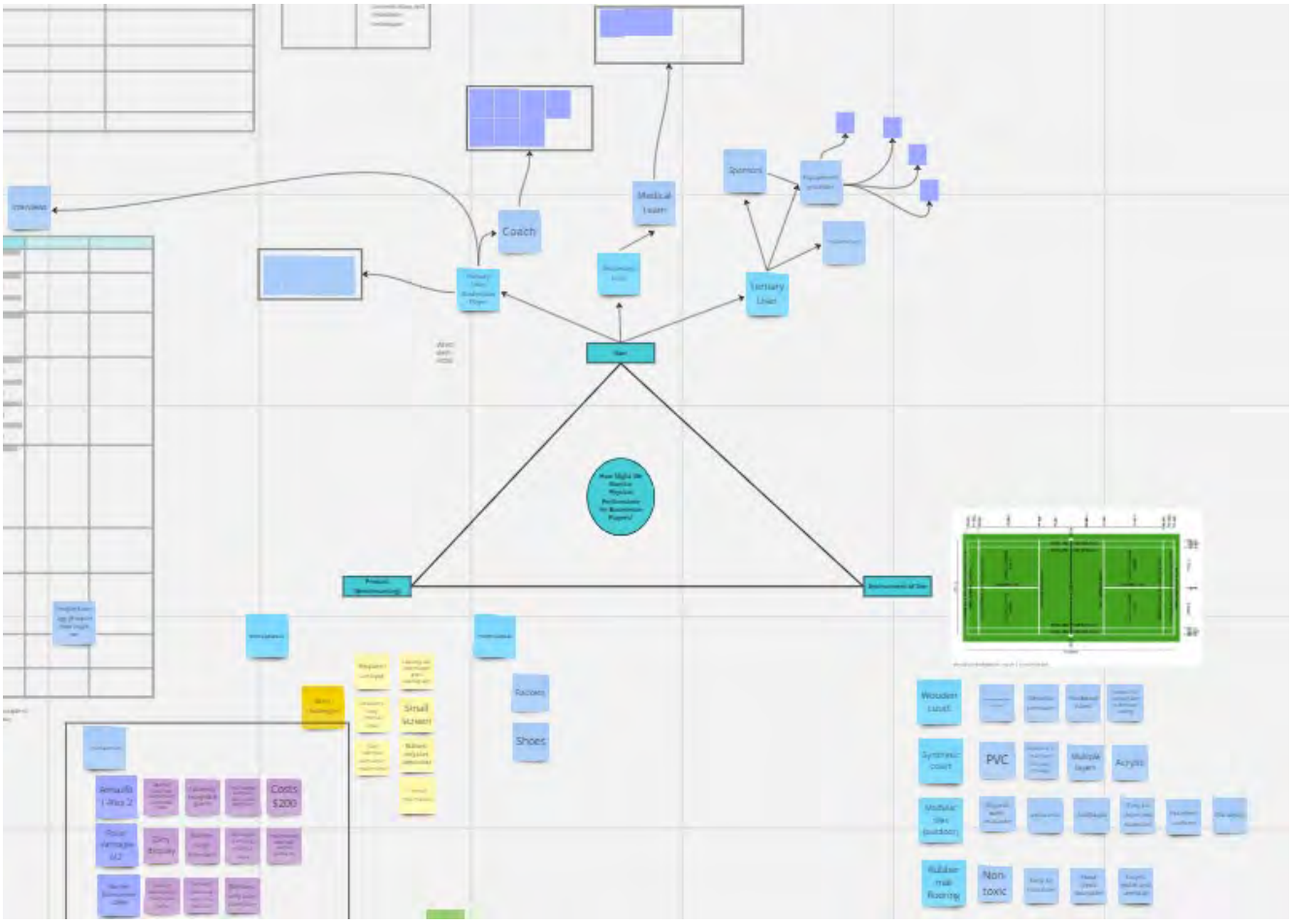


Figure 32 - MIND MAPPING

4.1.3 Ideation Sketches

During this stage of development there were a total of five different ideas that were created. They needed to be completely different too often the widest range of ideas to continue to develop. These sketches were down using a Wacom tablet in Adobe Photoshop, using this method of sketching was very useful later in the design process. These looked at help badminton players from training, competition, and mitigate risk of injury perspectives.

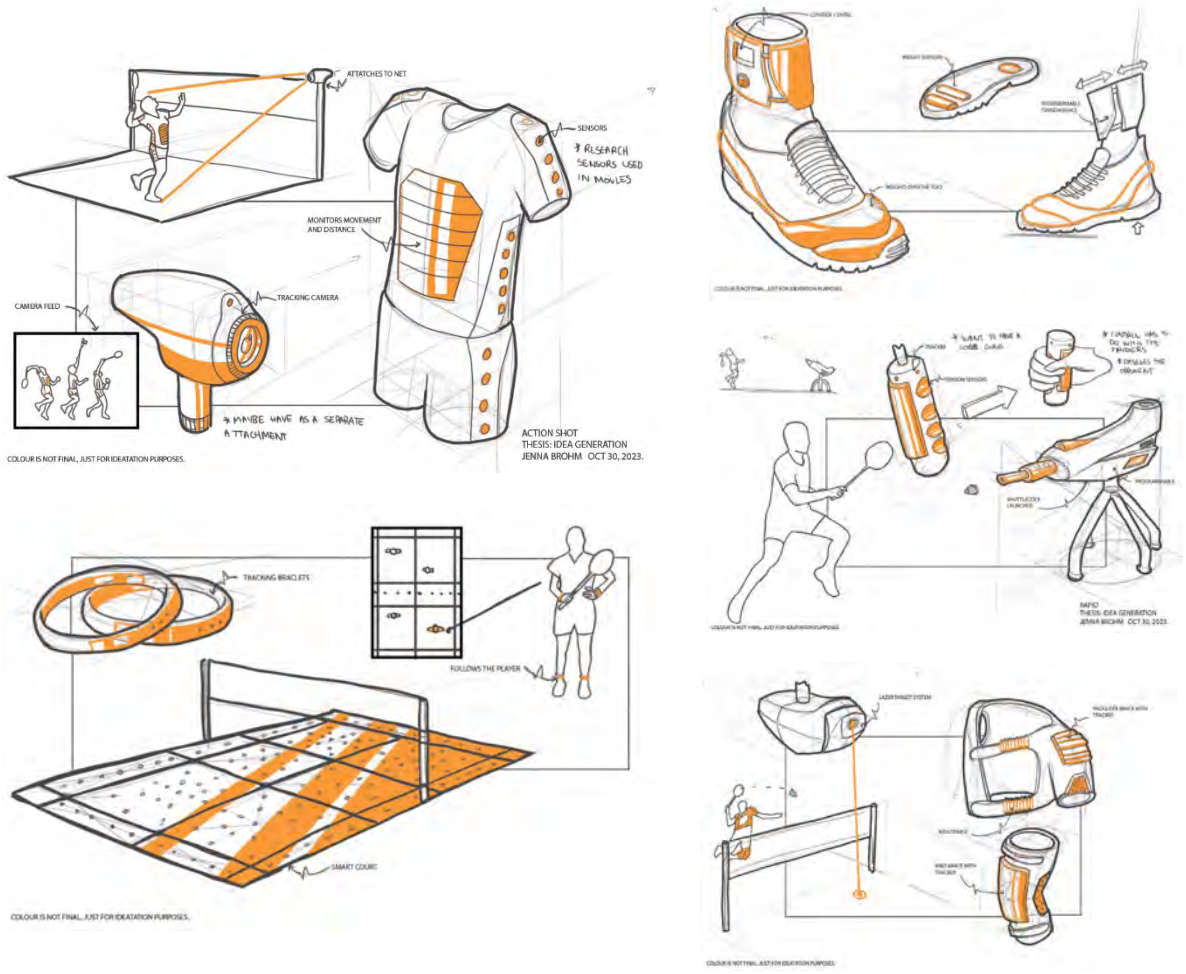


Figure 33 - IDEATION SKETCHES

4.2 Concept Exploration

From the ideation phase, four concepts were chosen to be combined as they showed more potential as a family of products. The ones to go forward were sketches 1, 2, 3, and 4. Sketches 1 to 3 were combined into one concept and 4 continued to develop as the second concept. These showed the most potential to be evolved into a solution. For concept one the main changes were to make the three separate ideas work together. For the second concept it had to become a smart court that would assist with training. It had to show which types of training it would focus on and how that would be beneficial. Both focused on training as technology is not allowed in competitions.

4.2.1 Concept One

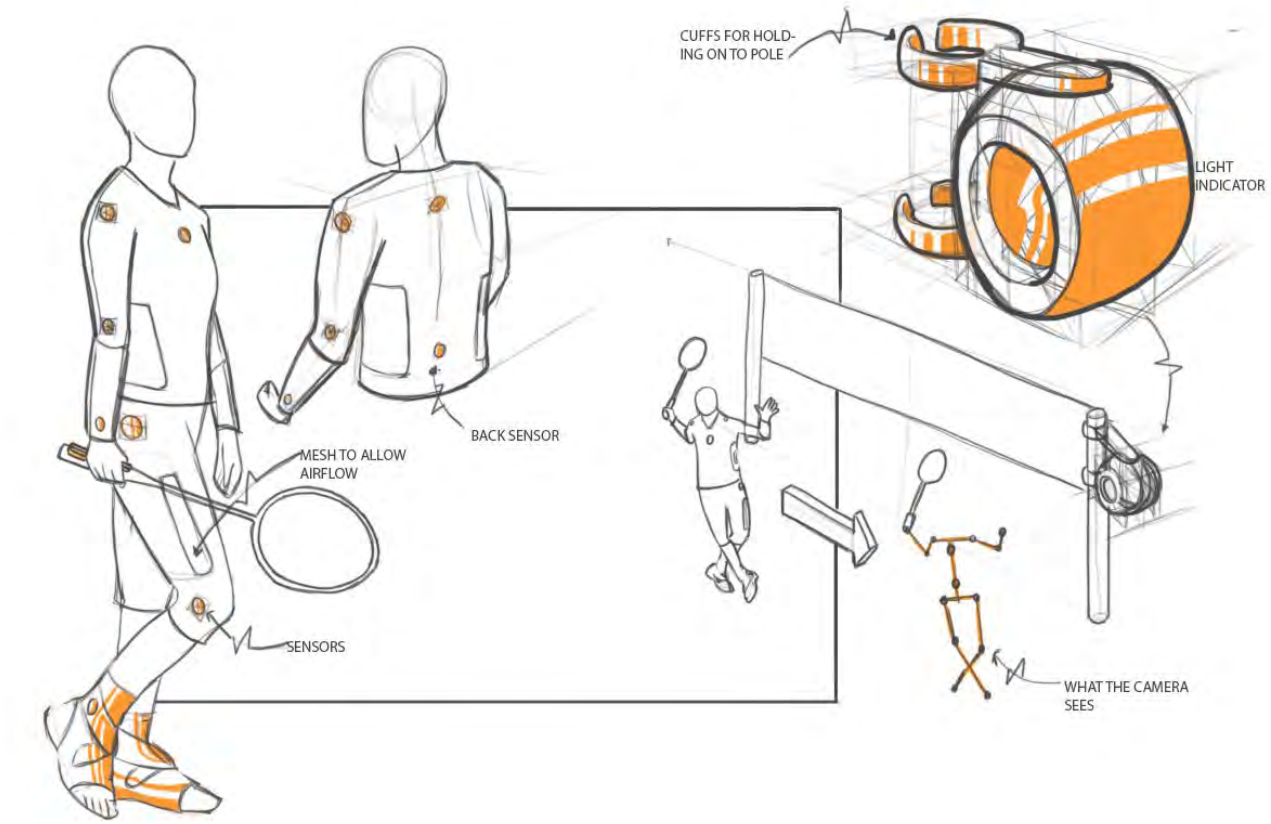


Figure 34 - CONCEPT 1

Concept 1 was to become a family of products focusing on the improvement of training and proper technical skills in badminton to mitigate the risk of injury. They were stronger and more compelling together than they were apart. The suit would be to track the body's movement and the racket would track shot training. The goal of this concept was to shine light on how training could change to suit the individual needs of each player. The camera needed a way of tracking areas of the body which were most at risk of being injured. Those areas are the ankles, knees, lower back, and shoulders. As ankles had the highest risk of injury a brace was added. The goal of the brace was to prevent the ankle from twisting too much and to keep it aligned with the knee. This would lower the risk of injury. Even with the high-risk

areas being monitored there was no reason to just focus on those. It was decided to monitor the entire body by creating a virtual skeleton of the player. All these components together would be able to monitor the entire body.

4.2.2 Concept Two

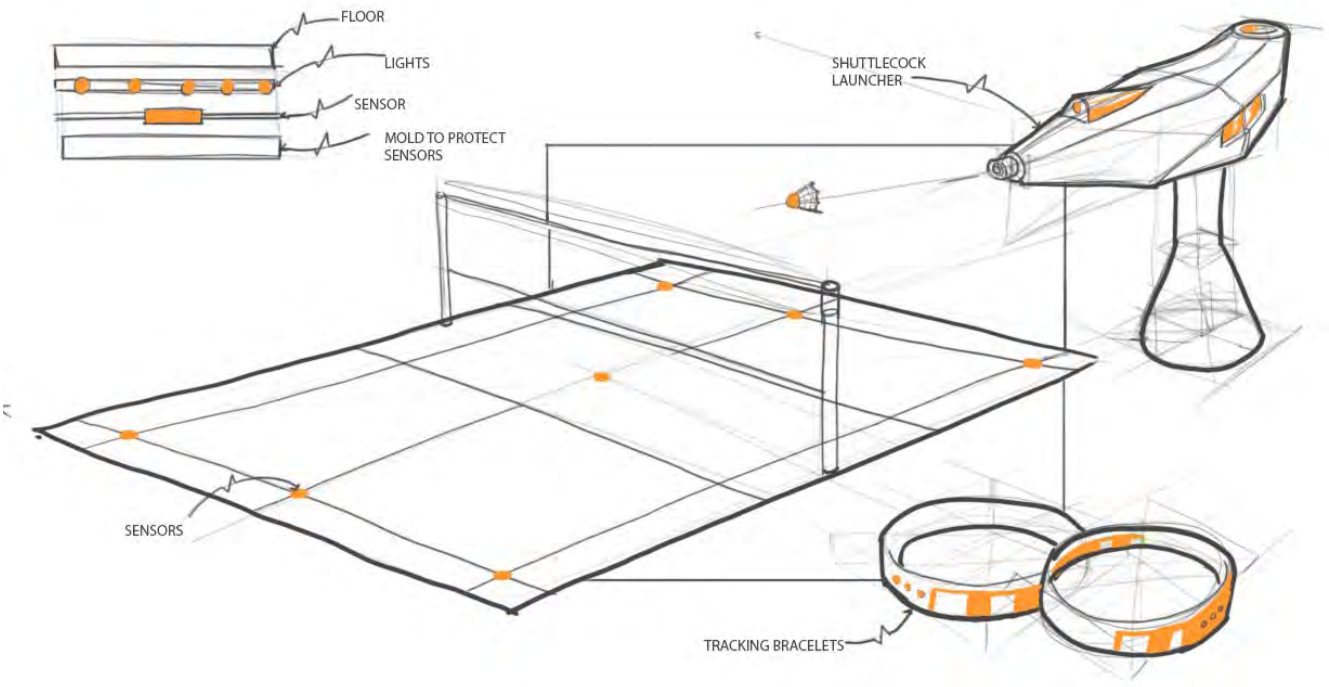


Figure 35 - CONCEPT 2

This smart court was designed to help with shadow training and shot practice. The player would wear wrist sensors that a shuttlecock launcher would be able to track. The launcher could be set to a variety of levels for continuous improvement. It would fire a shuttlecock at different speeds and to different locations on the other side of the court. This would cause the player to run and hit the shuttlecock back to the launcher. The player would then have to run back to the center of the court before the next shuttlecock would be launched. The other side would also light up so players could

practice their aim. These skills are important in a competition and would increase the three main points of badminton: stamina, speed, and power.

4.3 Concept Strategy

Moving forward with these two concepts allowed for more improvements, specifically in the ergonomics of the users. This was very important for concept one which includes a wearable suit for tracking. The second concept did not require as much focus for ergonomics since only the wrists, hands, and feet came in contact with the system of products. Adobe Photoshop was used for most of the sketches. Although, Adobe Illustrator was used for the product schematics. This was to show the main points and elements that would be included in both concepts.

4.3.1 Concept Direction & Product Schematic One

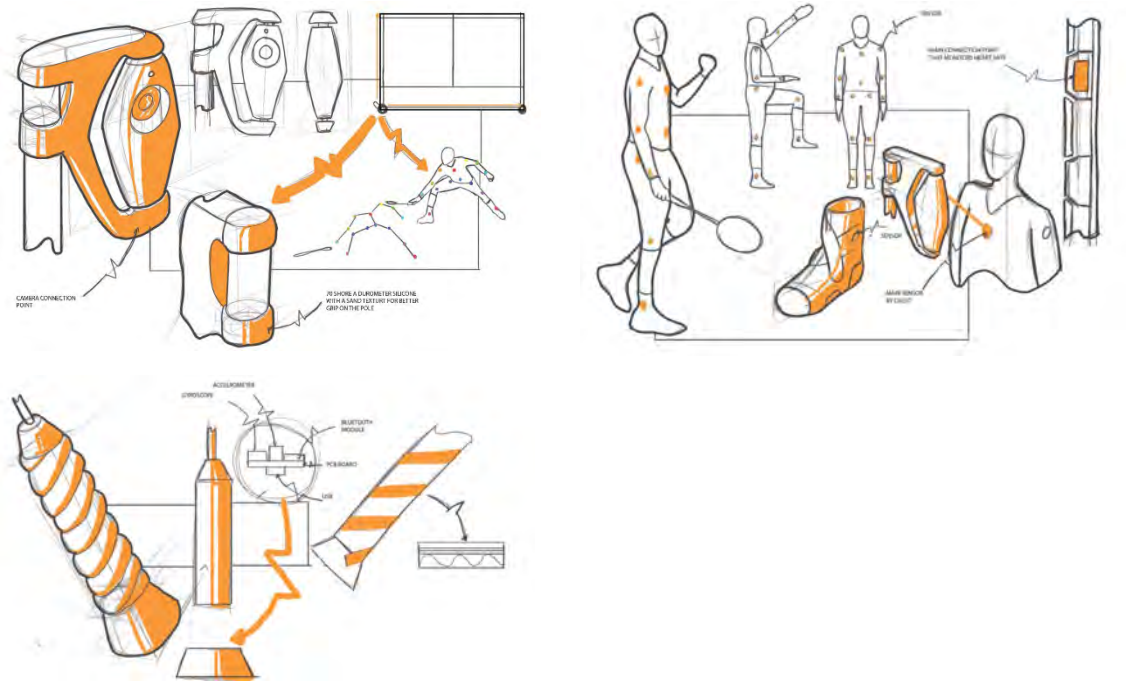


Figure 36 - CONCEPT 1 REFINEMENT

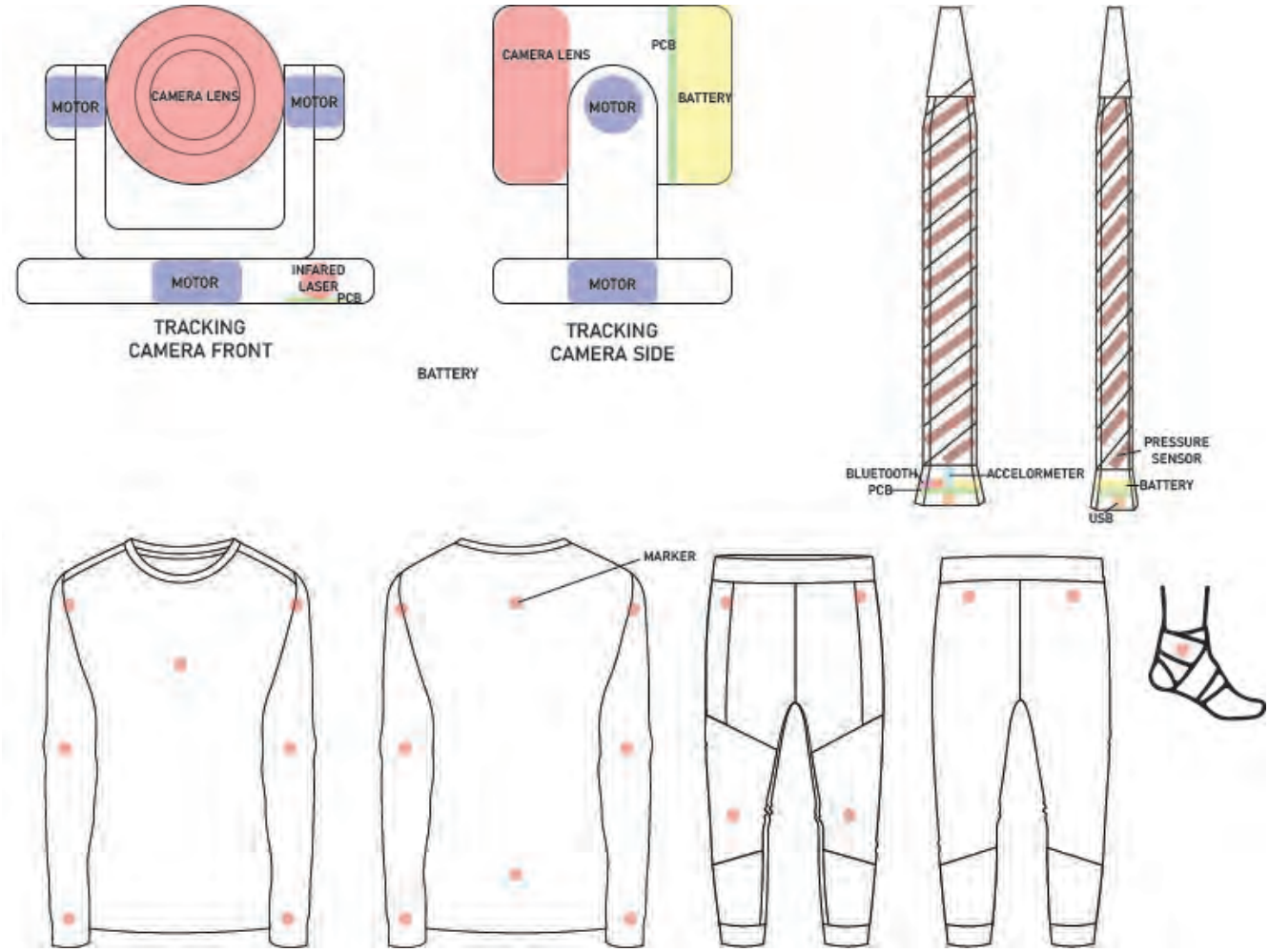


Figure 37 - CONCEPT 1 CONFIGURATION DIAGRAM

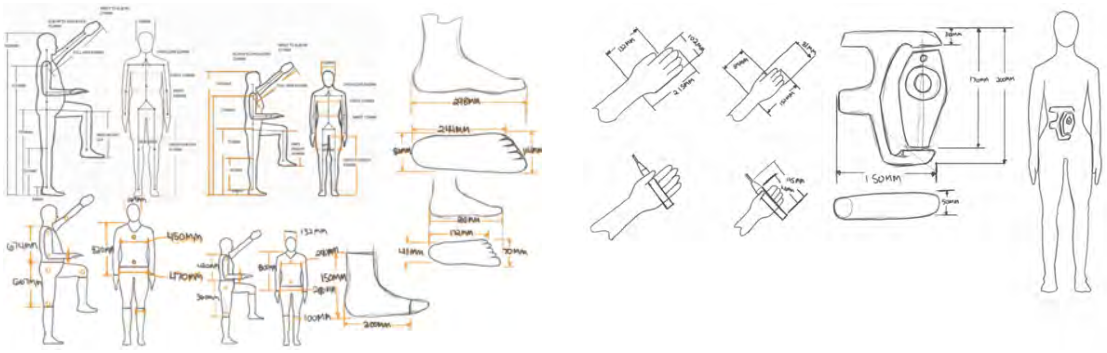


Figure 38 - CONCEPT 1 PRODUCT SCHEMATICS

4.3.2 Concept Direction & Product Schematic Two

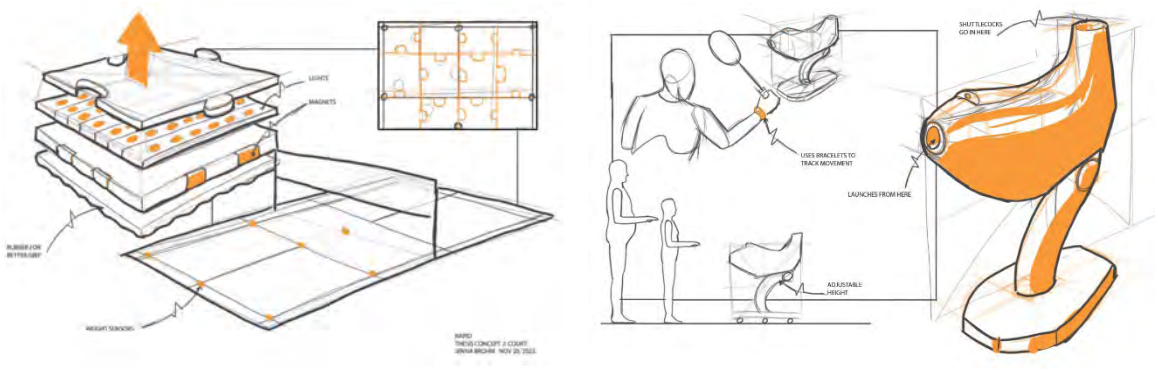


Figure 39 – CONCEPT 2 REFINEMENTS

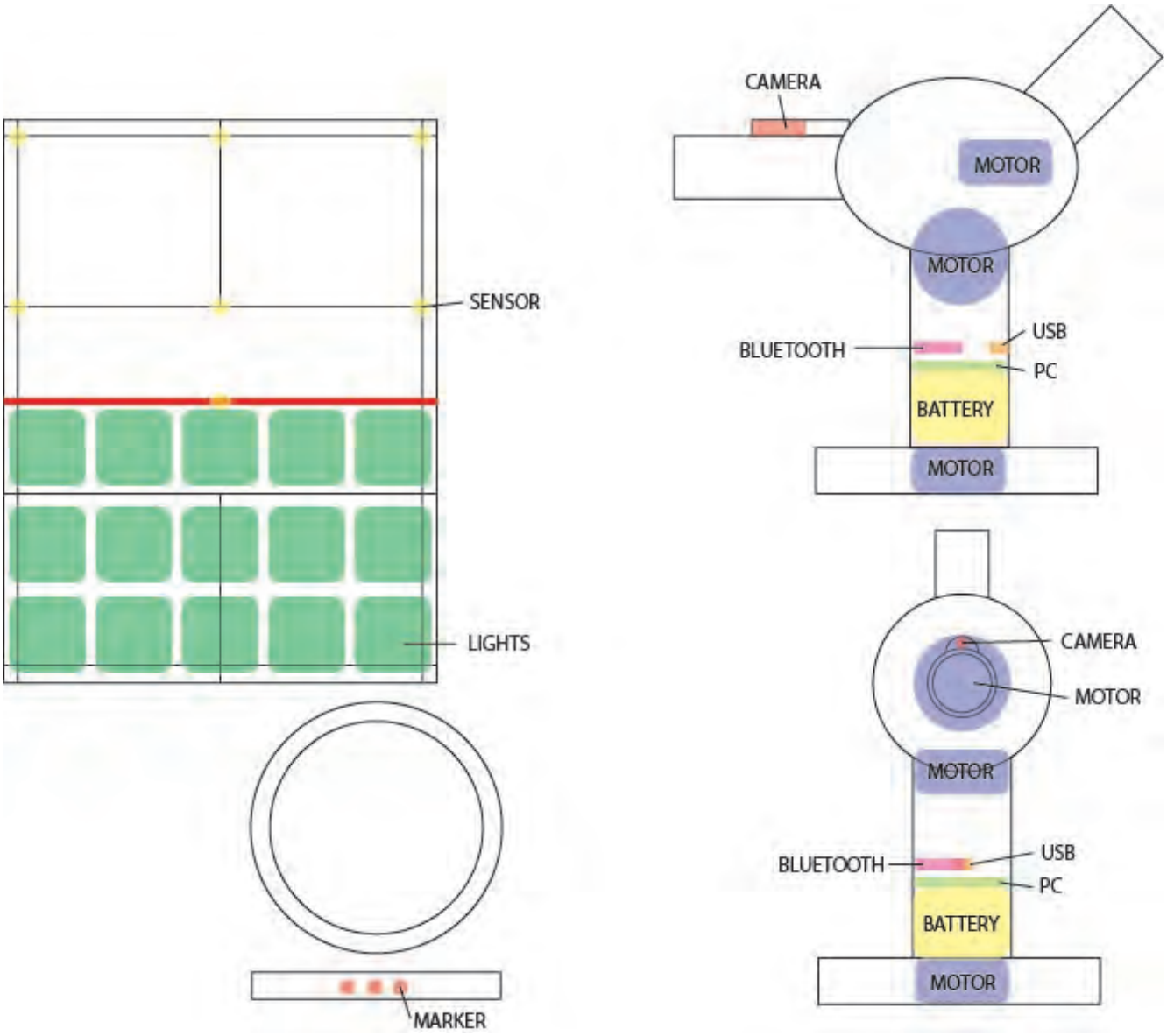


Figure 40 - CONCEPT 2 CONFIGURATION DIAGRAM

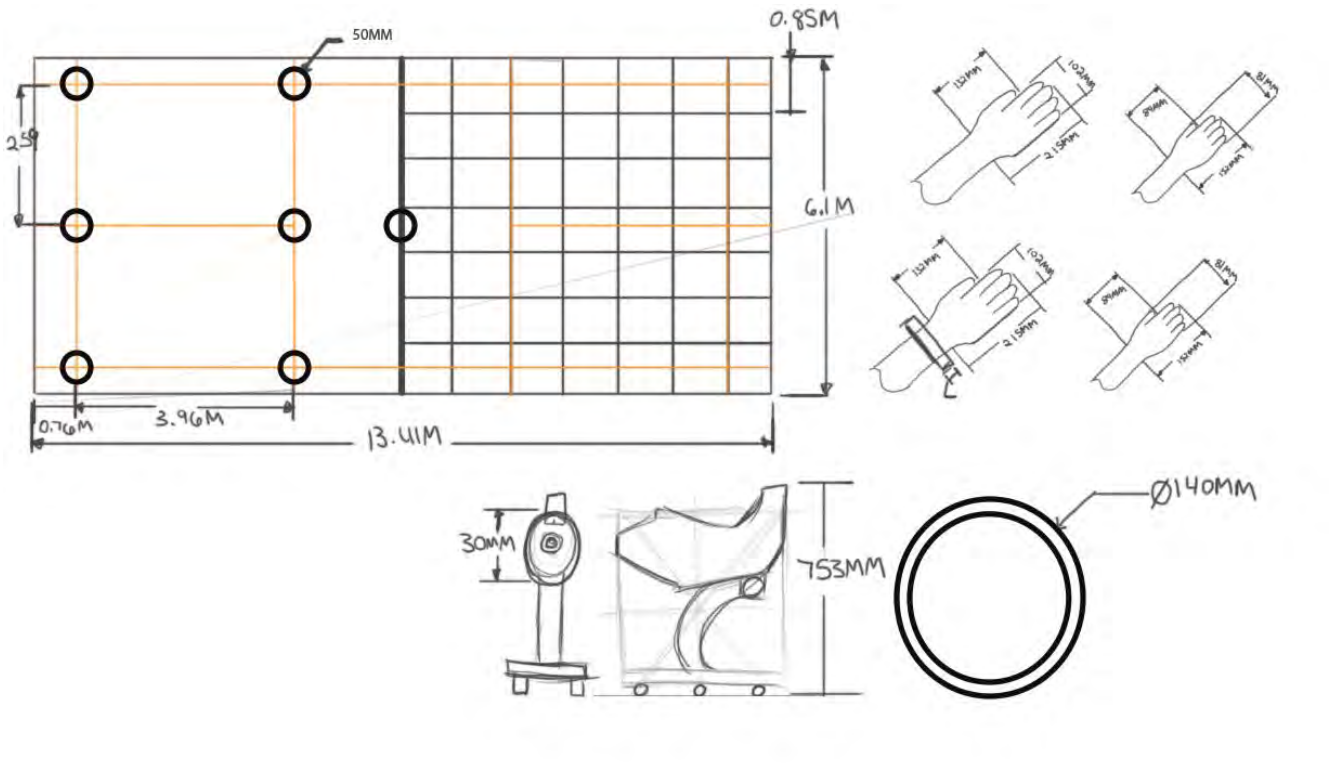


Figure 41 - CONCEPT 2 PRODUCT SCHEMATICS

4.4 Concept Refinement & Validation

After careful analysis on which of the two concepts had the most viable and functional solution to monitor badminton players, concept direction one was chosen. This allows for the aesthetics and detail refinements to be developed further. Concept refinements are needed to connect more with badminton the sport. Regarding the suit, it must contain copper stitching and sensors without looking too much like a superhero suit. It will have to be a balance between technology and sport apparel. The racket must work for a variety of users while still looking connected to the rest of the system family. As for the camera, it needs the most refinement to connect with badminton while still having the form requirements it needs. The detailing and refinements will take all these products into the future.

4.4.1 Design Refinement

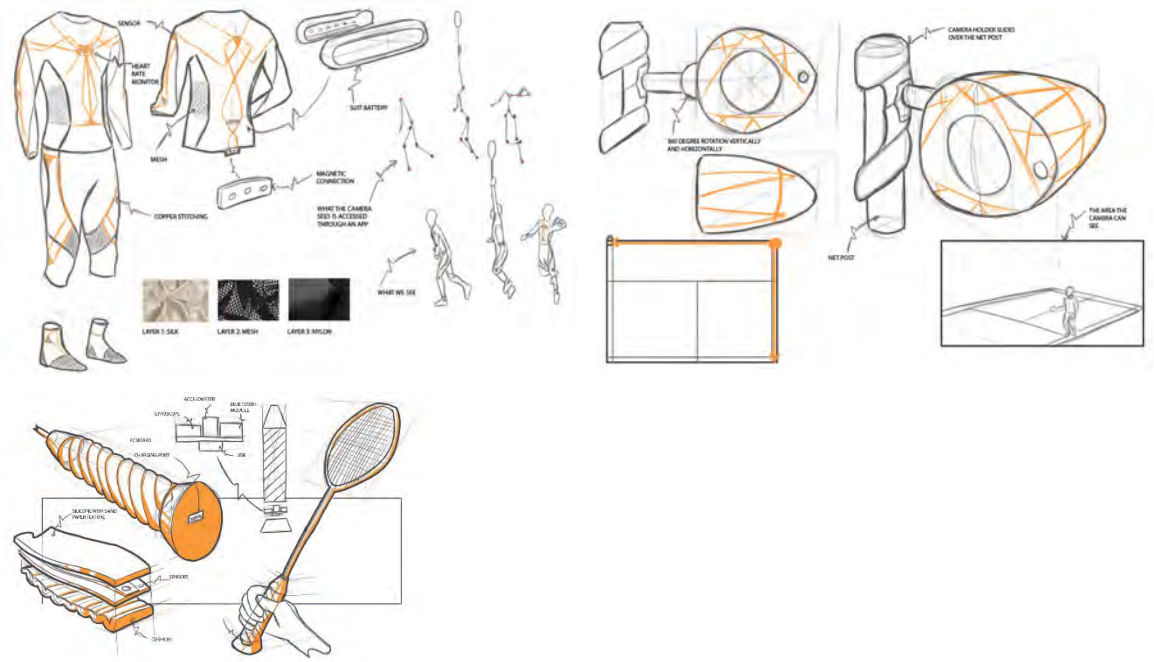


Figure 42 - DESIGN REFINEMENT

The purpose of the stitching and shapes in these products is to not only compliment the body, but also show a sign of strength. They are dynamic to show the drive that players must optimize their physical fitness as badminton players. Although, there is still room for the designers to look more cohesive and work together. That similarity will give a stronger drive for players and coaches to use these products. It is also able to let the skin breathe and the body bend. These products can continue to grow together to become even better in the end.

4.4.2 Design Development

Once the base of the designs was finished it was time to focus on detailing. This was to adjust the overall aesthetic and any slight function changes. How the connection between sensors still had to be adjusted and how that connection would move over the body. Sensor shapes and shapes made using fabric for the suit were crucial to provide a sporty appearance. The camera also needed detailing changes as it was too basic and lacked characteristics. Buttons

were still needed to connect the suit to create a family of products. This was taken forward to develop the two main products together.

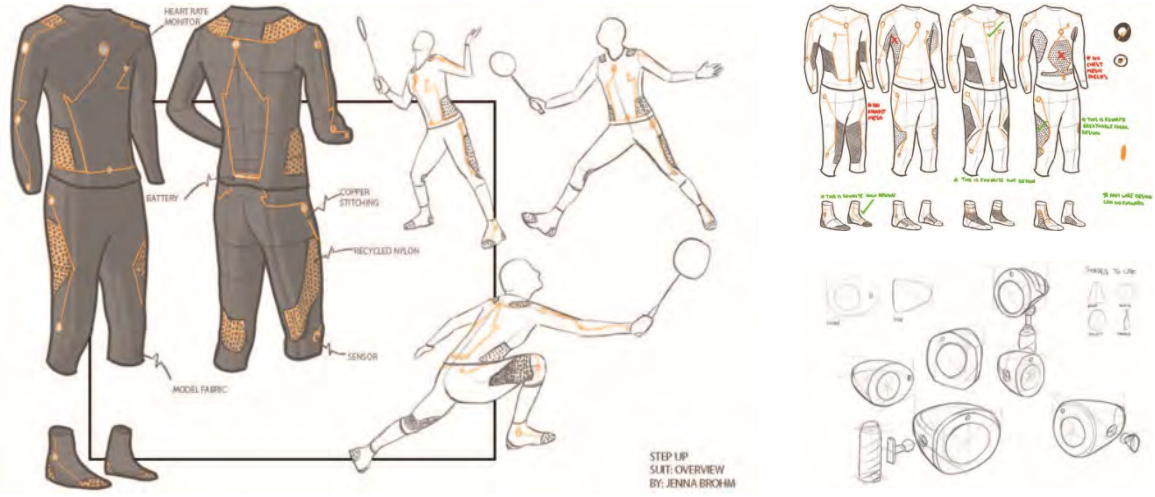


Figure 43 - DETAIL DEVELOPMENT

The end results showed that dynamic lines and cuts would provide an aggressive appearance. While the bodies of both products stayed organic, they could still have dynamic angles painted or stitched.

4.4.3 Refined Product Schematic & Key Ergonomic

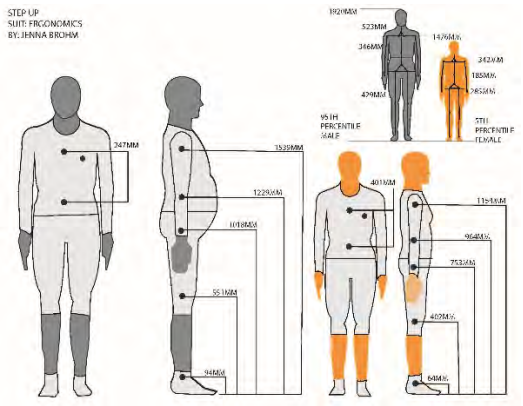


Figure 44 - REFINEMENT PRODUCT SCHEMATIC & KEY ERGONOMIC SUIT

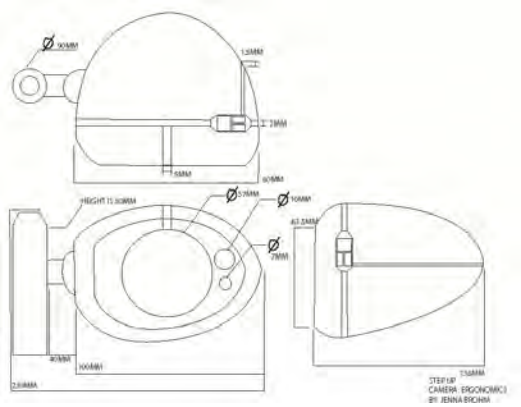


Figure 45 - REFINEMENT PRODUCT SCHEMATIC & KEY ERGONOMIC 2

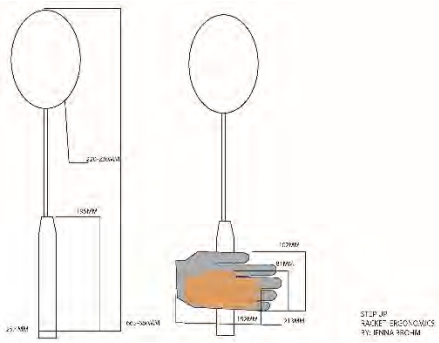


Figure 46 - REFINEMENT PRODUCT SCHEMATIC & KEY ERGONOMIC RACKET

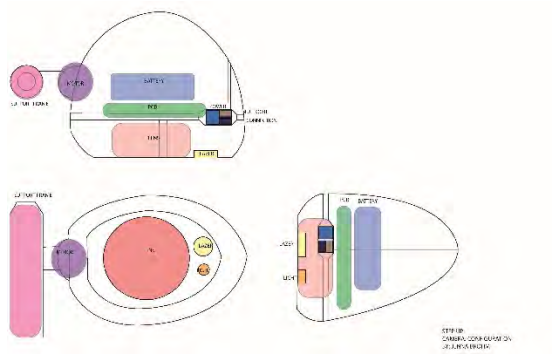


Figure 47 - REFINED PRODUCT SCHEMATIC & KEY ERGONOMIC CAMERA

4.5 Concept Realization

The concept was finalized focusing on the wearable suit with sensors and a camera to track player movement. It uses the human body for inspiration from both a physical and aesthetic point of view. More mesh is added to the areas of the body where there are higher levels of heat, armpits, back of the knees, and upper back. The conductive ink and

colour changes are asymmetrical for a sportier look. To achieve the most accurate reading of collected data, multiple sizes of the suit will be available to best track the individual's movement. The ideation phase included aesthetic changes to both the camera and suit to not only fulfil their needs, but also connect with badminton the sport.

4.5.1 Design Finalization

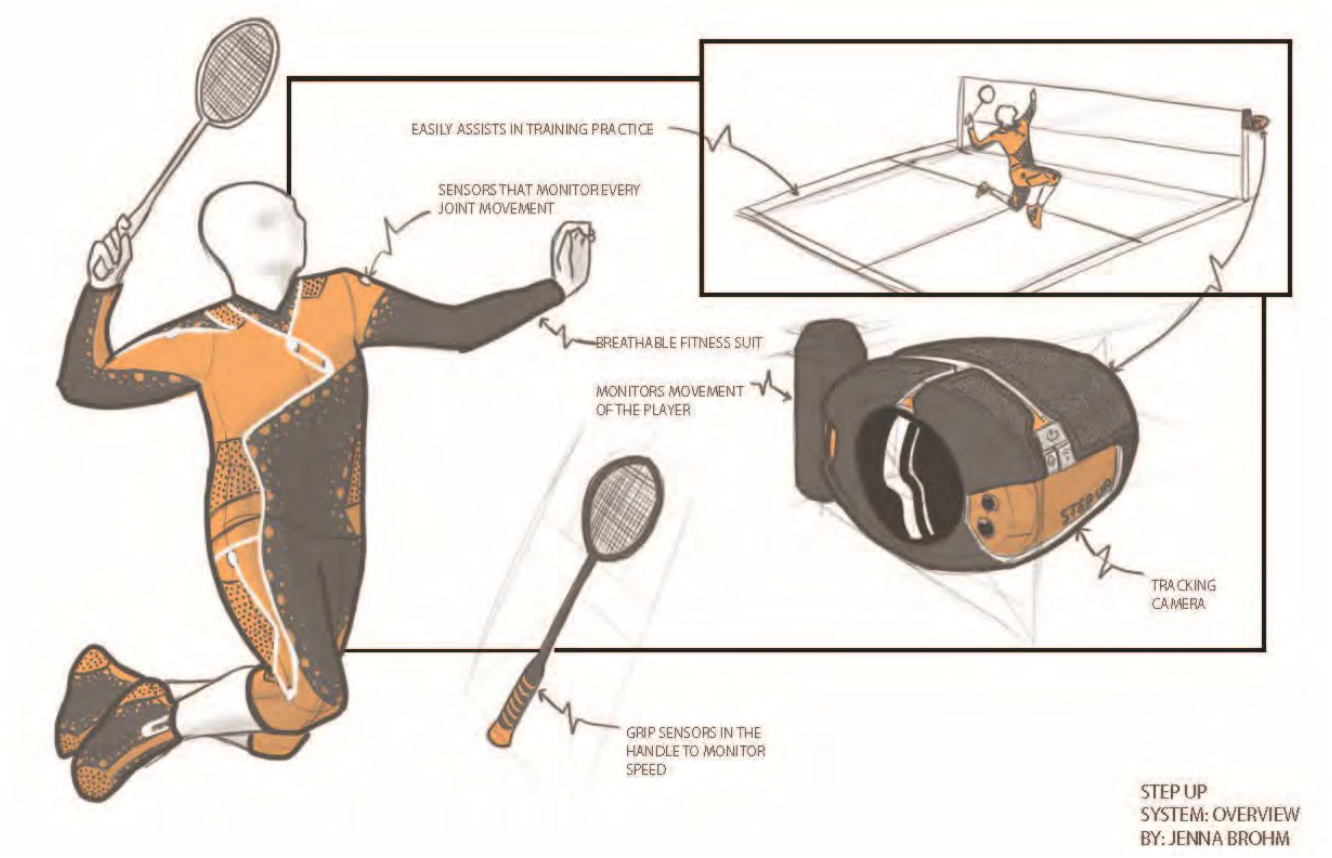


Figure 48 - DESIGN FINALIZATION

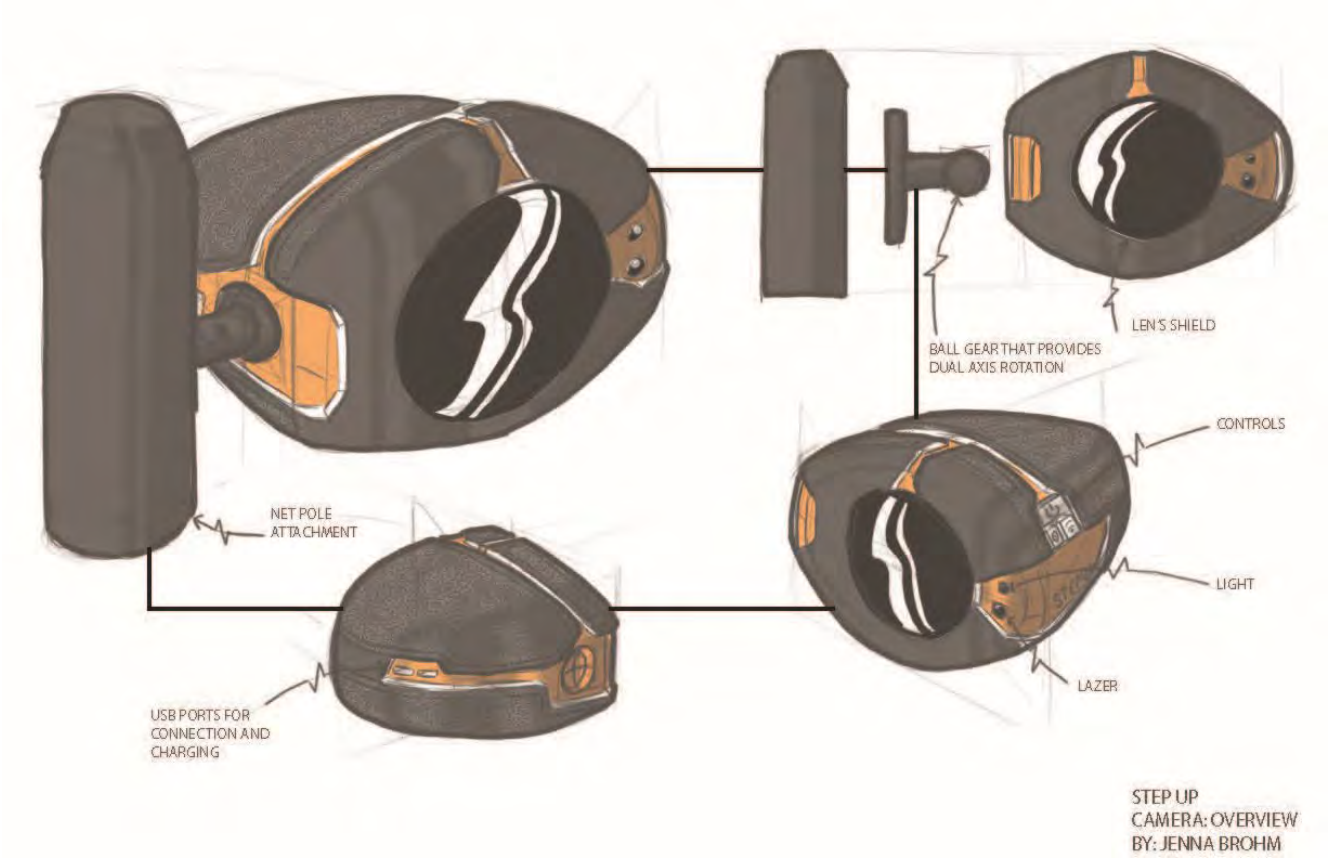


Figure 49 - DESIGN FINALIZATION CAMERA

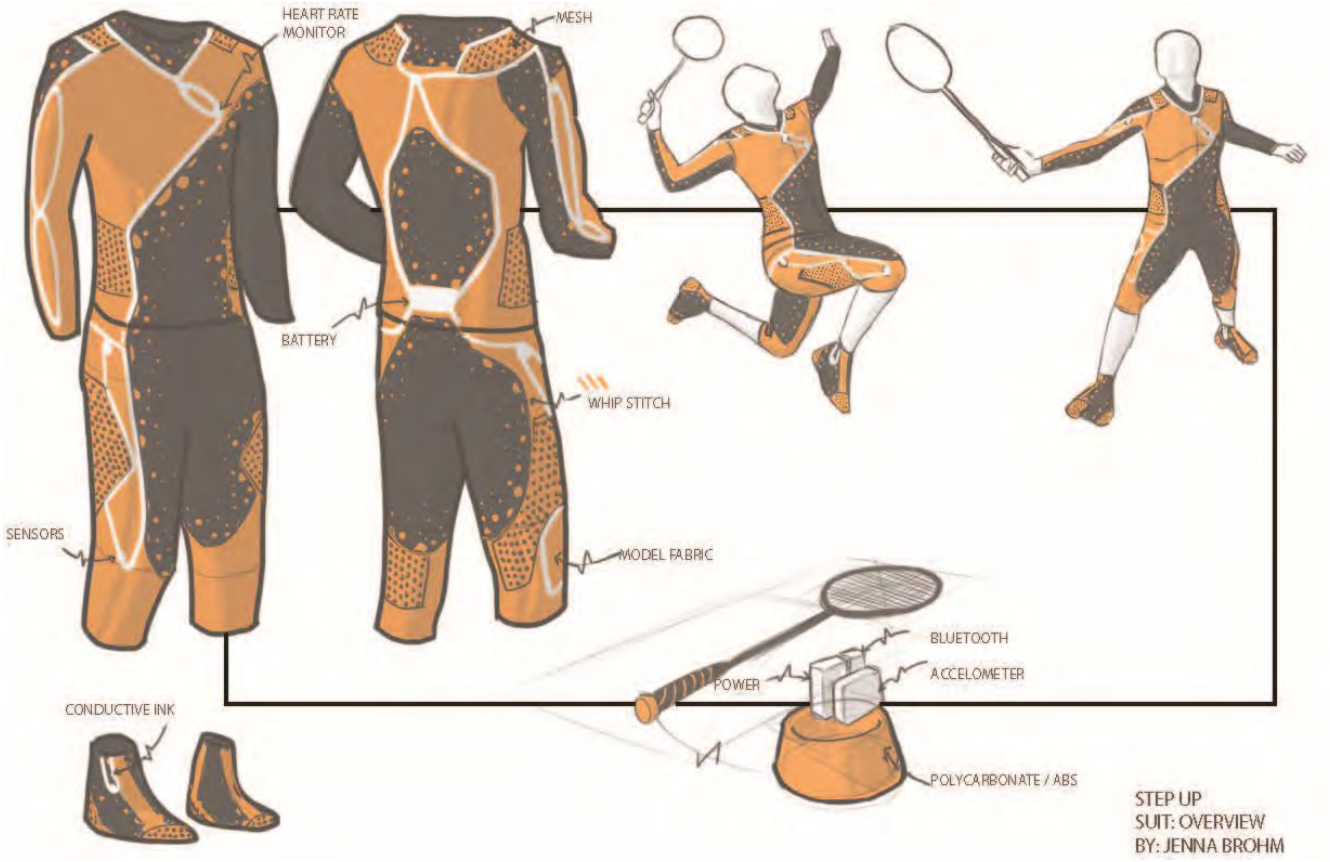


Figure 50 - DESIGN FINALIZATION SUIT

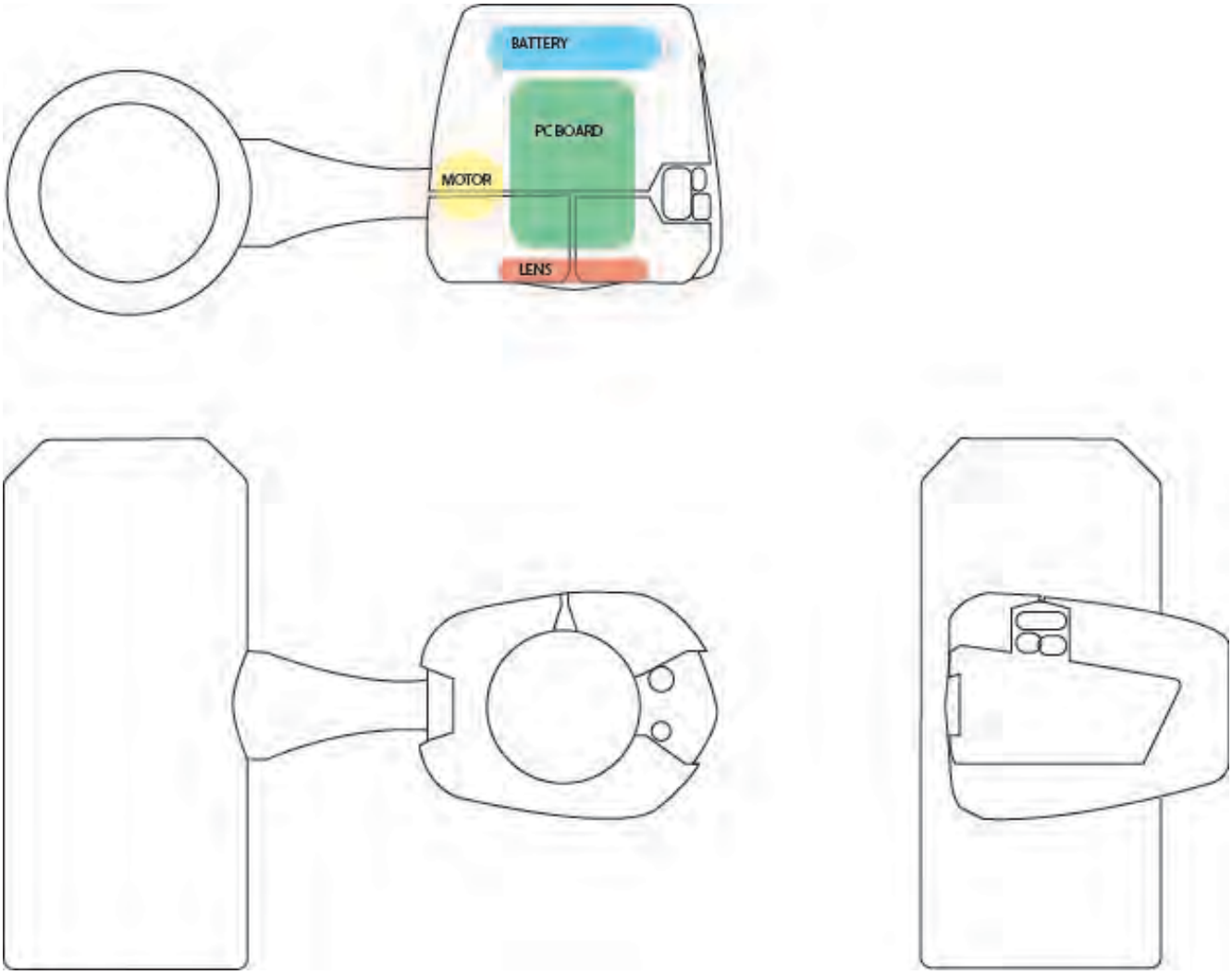


Figure 51 - DESIGN FINALIZATION CAMERA

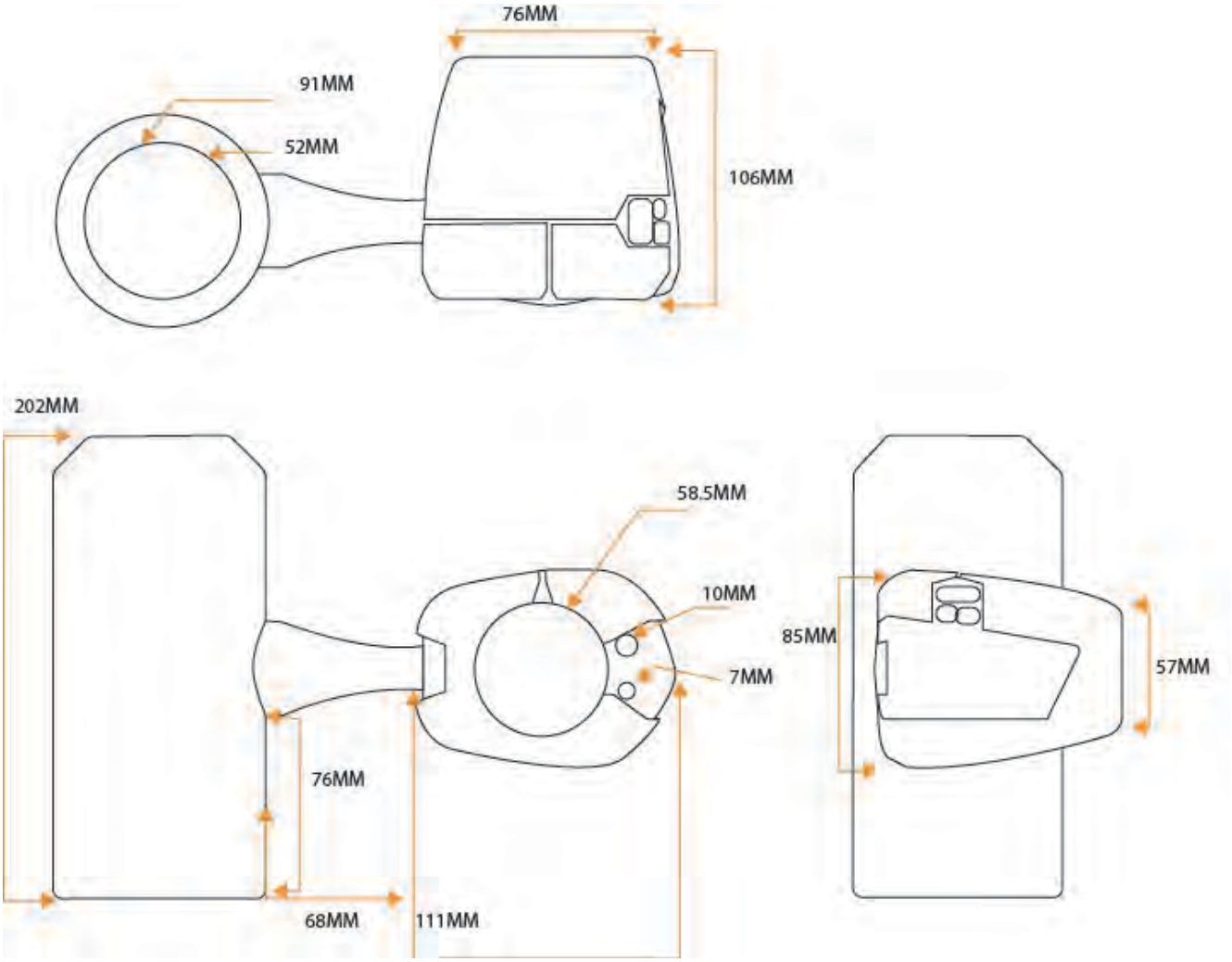


Figure 52 - DESIGN FINALIZATION CAMERA DIMENSIONS

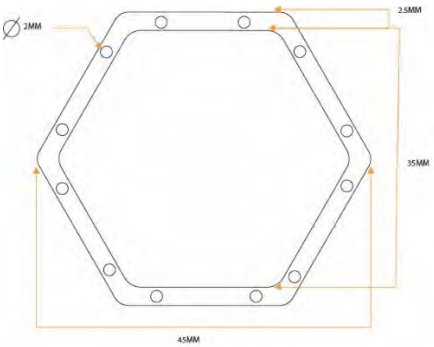


Figure 53 - DESIGN FINALIZATION SENSOR DIMENSIONS

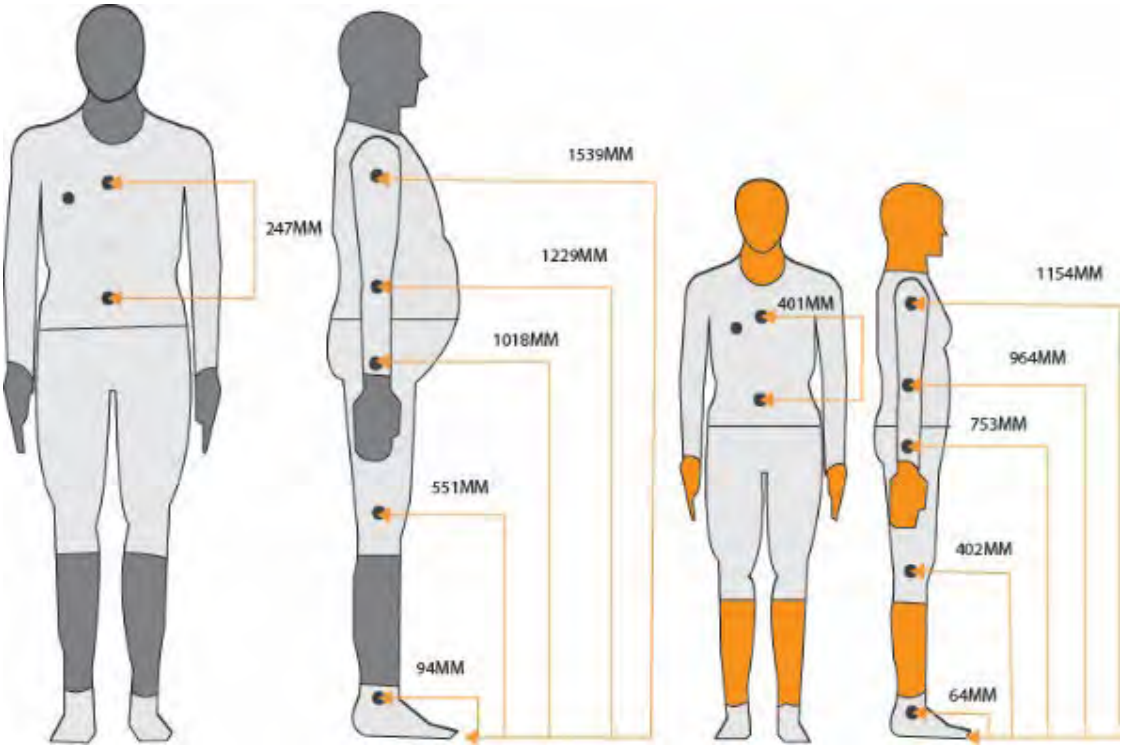
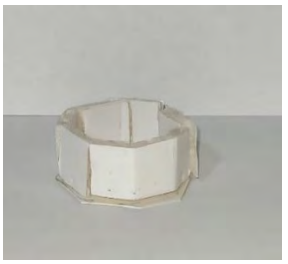


Figure 54 - DESIGN FINAL SUIT DIMENSIONS

4.5.2 Physical Study Models

A sketch model was made at a life size scale for both the camera and suit. The camera was mainly made of foam with some foam core to provide strength in certain sections. Clothing was used for the suit to show where sensors would be and where materials would change. These models helped to point out possible problems that could be encountered in the future. Which directed which model manufacturing methods would be used. Sadly, the suit sketch model did not help with using CLO 3D to create a CAD version of the suit.

Figure 55 - PHYSICAL MODEL SUIT



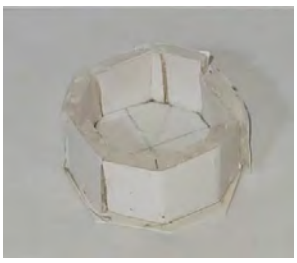


Figure 56 - PHYSICAL STUDY MODEL RACKET

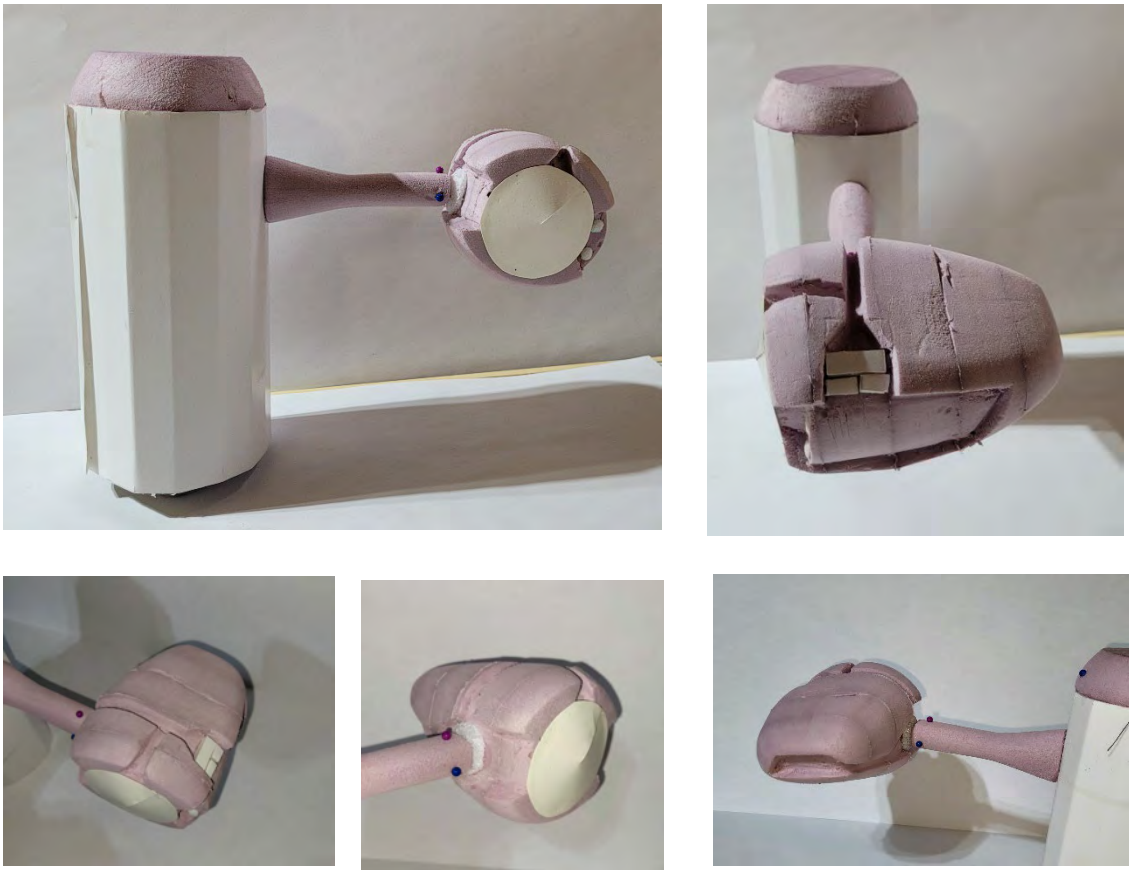


Figure 57 - PHYSICAL STUDY MODEL CAMERA

4.6 Design Resolution

Step Up's final design includes the basic needs of both players and their coach to provide the best benefits. Focusing on the requirements of being lightweight and flexible to prevent interference of play. The suit is tight to the skin to provide accurate data while still stretchable so the player can move freely. Step Up's camera is small for easy transportation and to not distract the player during play. To understand the time needed for a player to get from a paused position to reaching the shuttlecock is required to judge how to adjust their training. This monitors the movement of every joint of the body. Tracking how long it takes to move from one area to another and alignment of the arm when hitting the shuttlecock. With the tracking camera able to follow the sensors, rotating to view the entire court on one side. As it is designed to work with a sport, the aesthetic is more dynamic to have a powerful feel to all products. They have changed a lot to have more character and reflect the feeling associated with badminton.

The figures show the final form of both camera and suit with all the considerations listed above before jumping into CAD. Both Solidworks and CLO 3D will be used to create the products for Step Up.

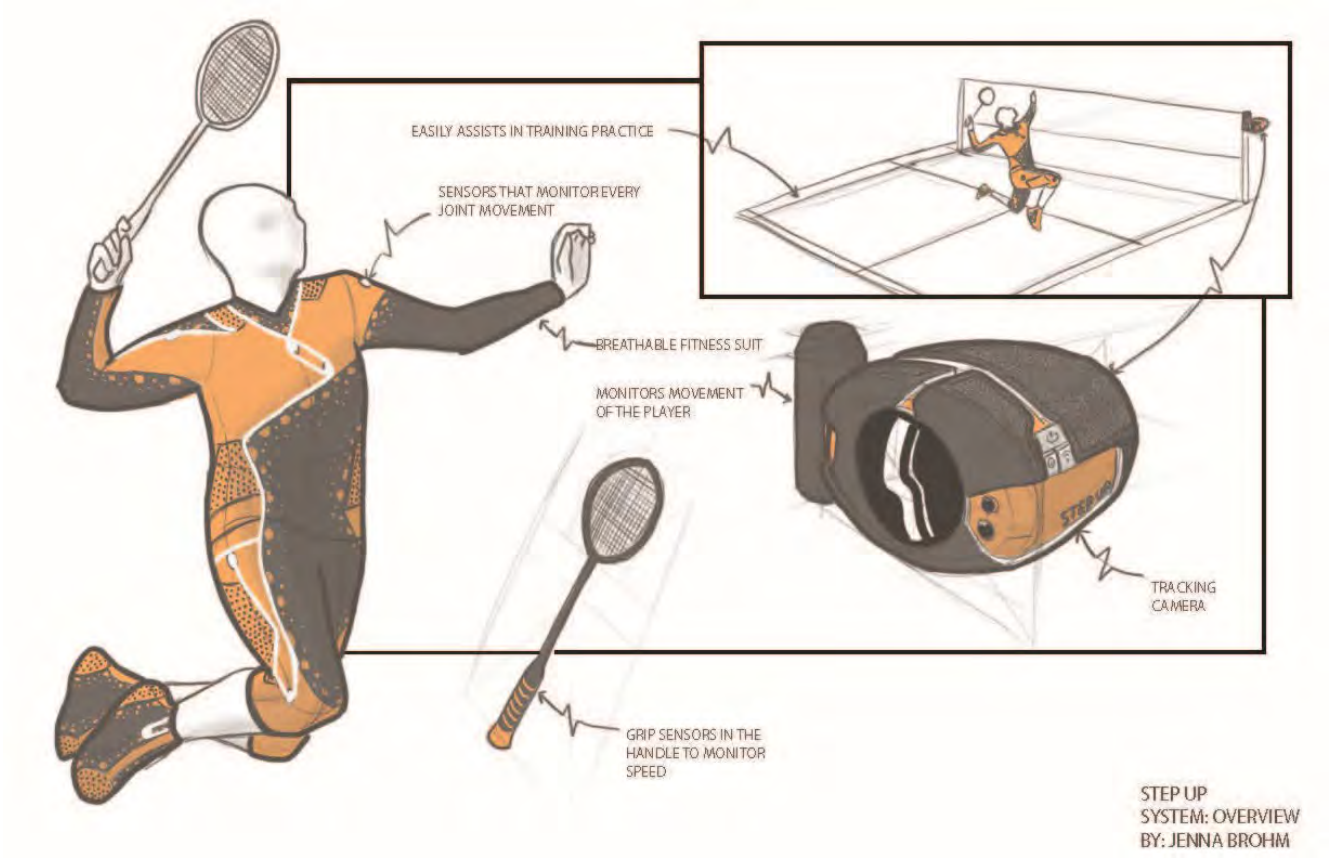


Figure 58 - DESIGN RESOLUTION

4.7 CAD Development

Once the designs were finalized it was time to put them into CAD programs. Solidworks was chosen for the camera, sensors, and racket attachment. This is because of experience with this program and the connection it has with KeyShot for rendering later. All these components would later be 3D printed. CLO 3D was chosen as it is the most common clothing CAD software and provided an opportunity to try something new. The suit will be made by a seamstress with iron-on materials. It will be rendered and animated for the video within CLO 3D.

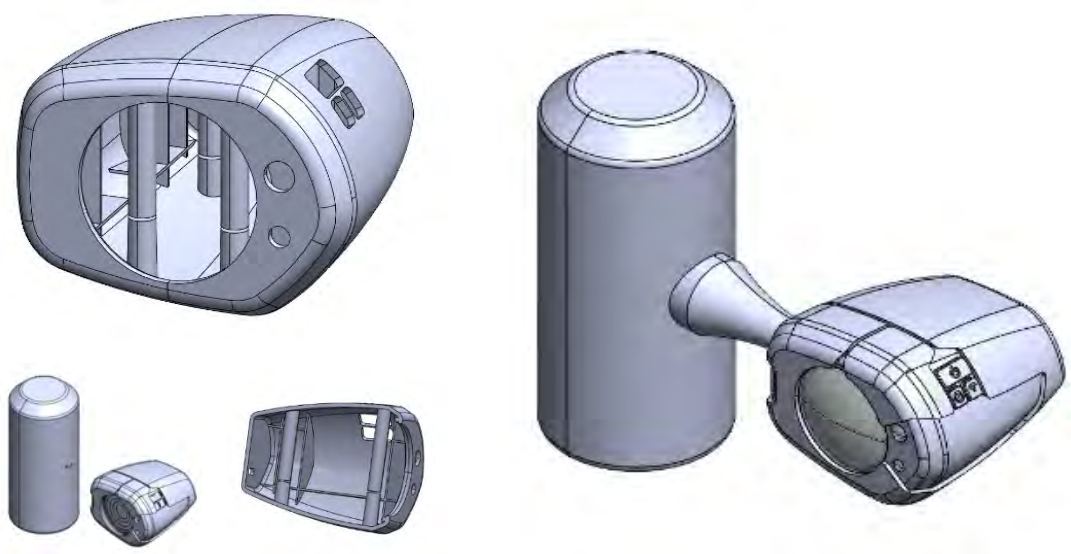


Figure 59 - CAD DEVELOPMENT

Figure 60 - CAD (CLO 3D) DEVELOPMENT

4.8 Physical Model Fabrication

The physical model fabrication for the camera was straight forward. The parts would be 3D printed thanks to Agile Manufacturing Inc. Once received they would be sanded, painted, and then assembled. The suit, however, proved to be more difficult as the original plan was to purchase the correct fabrics and sew them together. Multiple issues arouse with the fabric and graphic elements of the suit. In the end, a new plan was created using a variety of materials aside from basic fabrics. Once finished, both the camera and suit worked well together, with some minor changes.

Figure 61 - PHYSICAL MODEL FABRICATION 1

Here are the parts for the camera once received from Agile Manufacturing Inc. They are made of SLA plastic. They then underwent sanding of three different grit types before being painted.

Figure 62 - PHYSICAL MODEL FABRICATION 2

These are the sensors and camera once painted and fully assembled.

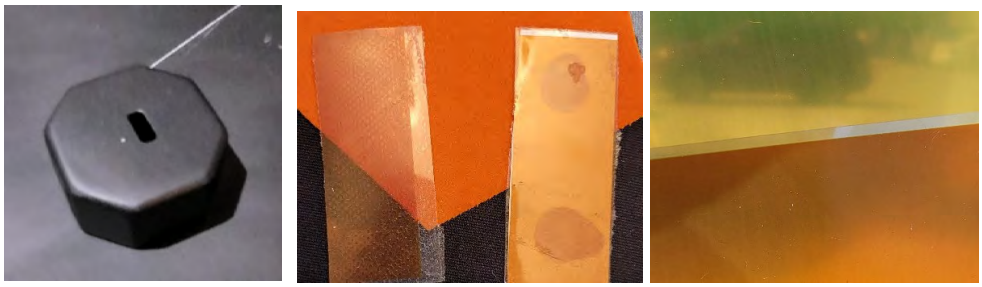


Figure 63 - PHYSICAL MODEL FABRICATION 3

This is the racket attachment and testing possible materials to act as the conductive ink. Finding a material to act as the conductive ink which moves over the entire body proved to be a challenge. Transparent paper was printed with the burnt orange colour and was then spray painted white on one side. The ink would be on both the orange and black fabric, to prevent that colour change is why one side was painted. Heat N Bond was used to connect the transparent paper on the suit.

Figure 64 - PHYSICAL MODEL FABRICATION 4

The suit was sewn together by a seamstress for the shirt and pants of the suit. Orand iron-on fabric was cutout and ironed on to the black nylon fabric. Figure 94 is a picture of the transparent paper ironed on to black nylon. Here is the orange iron-on fabric, transparent paper, and the mesh together.

Chapter 5 – Final Design

5.1 Design Summary

5.1.1 Description

Step Up is a system of products that are designed to monitor the physical performance of badminton players. It provides a deeper understanding of how the body moves to monitor improvements and lower the risk of injury. The system includes a wearable suit, a camera, and tracking sensors in the racket handle.

5.1.2 Explanation

Badminton players and coaches must rely on what they see or feel regarding monitoring improvement and preventing injuries. The eyes provide a very limited understanding of how the body moves and what is required for improvement. This makes training to benefit the individual difficult and tends to be generalized to a group needs. With the individual's needs not being met causes a higher risk of injury. Most players do not realize they have been injured until it causes them to miss some games. They tend to think any pain is minor and will play through it, which makes it worse. Common injuries are to the ankles, knees, and shoulders which are critical for good performance. Injuries and a lack of improvement prevent growth, putting an early end to a player's season.

Step Up is a solution that addresses all these obstacles by providing a deeper look at how the body moves. The suit has sensors on all the joints of the body including the ones in the racket which are tracked by the camera. This creates a digital skeleton which monitors heartrate, movement, speed, and rotation. Allowing each section of the body to pay

equal attention to monitor movement and any risk of injury. The data gathered can help a coach adjust training to help the individual. Step Up helps players improve their skills and lower the risk of injury to keep their season going.

5.1.3 Benefit Statement

Step Up is a system of products that includes a suit, racket sensors, and a tracking camera. Providing a deeper understanding of how the badminton player moves around the court to monitor improvements and mitigate the risk of injury. Training can be more specific to the individual's needs to develop their skills.

5.2 Design Criteria Met

5.2.1 Full Body Interaction Design

For the full body interaction of thesis, the 95th male and 5th female percentiles were used to get the best understanding. They were used throughout the design process as tracking the movement of a player had to work regardless of the player's body. This was very important for tracking players' improvement and lowering the risk of injury. To do this the sensors had to be as close to the joints as possible. The interaction design also had to allow for full body movement and not interfere with the sport of badminton.

Sensors are located on all the main joints, the chest, and the back to create a digital skeleton for tracking. This allows for coaches and players to understand the joints as individuals to make them work together as a system. Specifically, the knee and shoulder sensors as these areas have the highest risk of injury. The suit is skintight so these sensors can get an accurate reading of the player's movement. By tracking these sensors, the data gathered can track

heartrate, shots used, and speed of movement. This information can be used to adjust training to benefit the individual growth as a player. As well as shine light on areas that are at risk of being injured. Helping to improve a player's season.

The mesh on the suit is in areas that have a high temperature. This is to allow for proper airflow and for that heat to escape. Due to the suit being skintight and having sensors that could cause players to feel weighted down and overheat faster than normal. To prevent this, mesh has been put by the armpits, sides of the torso, centre of the back, and around the knees. This will allow that heat to escape and keep the player cooler for longer. Step Up is designed to get the most accurate data from a player so it cannot interfere with the player's movement or stamina.

The racket handle is designed to focus on a player's control over the racket. This is important as wrist rotation is how the player aims for where the shuttlecock will land. There are sensors to detect the strength of the player's grip on the racket. This shows when a player's joints lock up either due to age or stress. Joints locking up prevents the player from moving and causes a larger gap between noticing where the shuttlecock is and reacting. When this is detected, a coach will be able to adjust the training to counter it. By tracking the racket, it will show the speed at which the shuttlecock is hit and shot type used. In the end it will help make any necessary adjustments in training.

5.2.2 Materials, Processes, and Technology

Once the design for Step Up was finalized, it came to selecting the best materials and processes to fit the end goal. The fabric for the suit is made of beech trees, creating a semi-synthetic hybrid. It was chosen because 99% of the solvents are recycled and are already found in active wear. A silk underlayer is included to protect the player's skin from any possible irritation due to the sensors. The sensors, camera, and racket are made using recycled polypropylene due to

its durability. Manufacturing of the suit would be done by sewing the fabrics together. For the camera and sensors, those parts would be injection molded. For connecting the sensors there were multiple options, the main two being conductive ink and nanotech. Conductive ink was chosen as it can easily be added on to a pre-made garment and doesn't need to cover the entire body. Using sensors on the joints are to draw attention to specific areas that are needed to assist the player. Focusing on the entire body could overwhelm the viewer of the data and cause important information to be missed. These materials, processes, and technology help provide a deeper understanding of movement while having the same benefits as regular fitness attire.

5.2.3 Design Implementation

The cost of materials and manufacturing will change as new more sustainable methods are discovered. Step Up is designed to be sustainable to help the environment and provide little to no negative impact. The table below is the current bill of materials if this design is taken forward for manufacturing.

Bill of Materials					
HIGH-COST ITEMS					
Concept Items	*Description*	*Estimated Costs*	*Similarly Produced Items*	*QTY*	*Material*
Camera Body	Exterior of camera	$350	-	1	Polypropylene
Bluetooth Adapter	Wirelessly connect sensors to camera	$255	-	17	Polypropylene
Conductive Ink	Ink to connect the sensors	$224.83	Copper stitching	100 ml	Carbon conductive paint
Fabric	Black fabric	$54 total ($18 per meter)	-	3 meters	Model fabric (Beech tree)

	Orange fabric	$26 total ($13 per meter)	-	2 meters	Model fabric (Beech tree)
	Mesh	$29 total ($29 per meter)	-	1 meter	Mesh
Heart Rate Monitor	Tracks the player's heartbeat	$100	-	1	Polypropylene
MEDIUM-COST ITEMS					
Accelerometer	In the sensors to track speed	$70	-	15	Sourced
Gear Ball	Allows the camera to rotate on multiple angles	$56	-	1	Aluminum
Sensors	Tracks movement of the player	$50	-	15	Polypropylene
LOW-COST ITEMS					
Shield	Protects internal elements of camera	$45	Protective glass	3	Tempered glass and polycarbonate
Lazer Tracker	To find sensors	$30	-	1	Sourced
Net Post Attachment	Attaches arm attachment to net	$25	-	1	Polypropylene and rubber
Battery Pack	External battery pack	$25	-	1	Polypropylene
Lithium-ion Battery	To power the sensors and camera	$24 (for 8 pack)	-	8	Sourced
Lens	To record data	$21	-	1	Optical glass
PC Board	To hold data	$16	-	1	Sourced
Arm Attachment	Attaches camera to net post attachment	$15	-	1	Polypropylene

Racket Tape	Holds sensors to racket	$12	-	1	Rubber with adhesive
USB Ports	USB-B	$10	-	1	Sourced
	USB-C	$10	-	1	Source
Racket Attachment	Contains internal tracking elements	$10	Base of racket	1	Polypropylene
3000RPM Motor 200W	To rotate camera	$7.20	-	1	Aluminum

Table 12 - BILL OF MATERIALS

5.3 Final CAD Rendering

Figure 65 - FINAL RENDER 1

Figure 66 - FINAL RENDER 2

5.4 Physical Model

Figure 67 - CAMERA & RACKET MODELS

Figure 68 – SUIT MODEL

5.5 TECHNICAL DRAWINGS

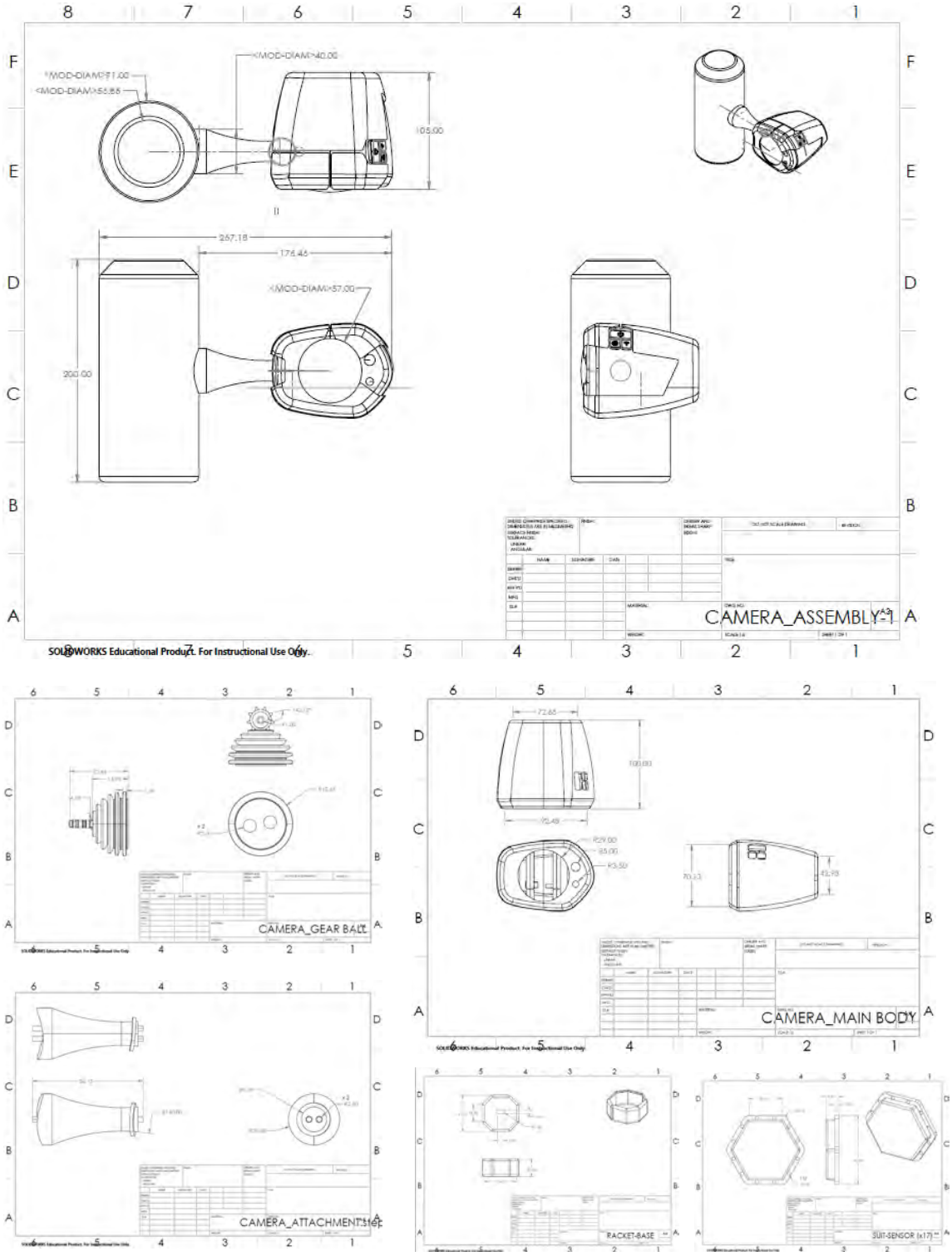


Figure 69 - TECHNICAL DRAWINGS

5.6 Sustainability

Sustainability has become a necessity in the world as global warming increases. As climate change continues more research is required to slow it down if not stop it. That is no different for this thesis project. Designing products to be sustainable is a part of the new normal, it is required to support the life on this planet. Every product will soon have a sustainable aspect to it to help the environment.

Step Up's main goal is to help badminton players monitor their improvements and mitigate the risk of injury. This does not mean that the environment must be hurt to help the player. Many aspects of both the camera and suit have been designed too little to have no negative effects on the environment.

The suit is made of model fabric which has 99% of the solvents recycled which is sewn using an electric sewing machine. Not only does this material already appear in fitness wear, but it is also made of beech trees. Able to provide the same benefits without harming the environment. Conductive ink is used to connect the sensors instead of nano technology due to its lower effect on the environment. Where nano technology would have to cover the entire suit, the conductive ink only goes in a straight line from sensor to sensor. This lowers the amount of material used and is better for the environment. Finally, all the sensors on the suit are made using recycled polypropylene. This helps prevent the need for new plastics to be made and helps keep old plastic out of the oceans. Sustainable products can provide the same benefits as non-sustainable products.

Jenna Brohm

The camera is made of recycled polypropylene with recycled rubber for the net attachment. Recycled polypropylene provides a protective shell for the camera at the risk of being hit by a shuttlecock. Not only is it durable, but it also helps prevent more chemicals from being released into the environment. Recycled natural rubber is used to keep a tight grip to the badminton net for the camera. It lines the inner column of the pole net attachment. That with the outer column being made of recycled polypropylene provides a steady support for the camera.

All these sustainable elements help to create a system that not only benefits the user, but also the environment. The eco-friendly fabric of the suit with the conductive ink prevents a waste of energy but still allows the user to move freely. All the recycled polypropylene parts provide durability to increase the life of Step Up. Injection molding uses less energy than most manufacturing methods. Sustainability works not just in the material choice but also in the manufacturing and lifetime of the product. The sustainable elements used in Step Up will provide a long stable life for this system of products.

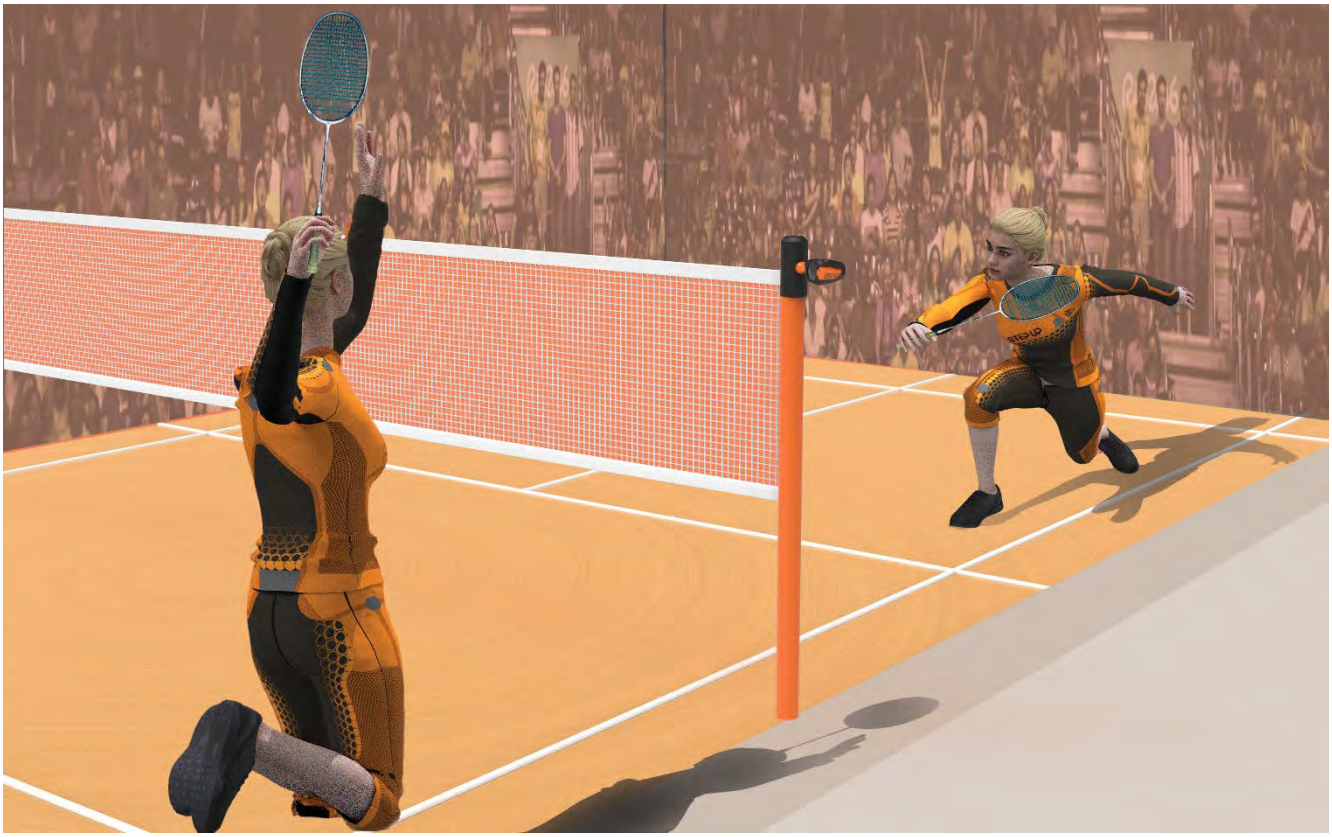


Figure 70 - CONCLUSION PHOTO

Chapter 6 – Conclusion

Badminton is a fast-paced sport which makes it difficult to track improvement and has a high risk of injury. To track one's improvement they must know their stamina, speed, and power over a period. This is very difficult to track as most information is gathered by what someone can see. While the eyes do help to some extent, they simply cannot get enough information to prove overly helpful. As for the coach, they often must focus on multiple players. This causes an individual's needs to be missed or forgotten. Injuries are often hidden until the pain prevents a player from participating. Sprains and strains are very common due to the technics necessary in badminton. Areas like the ankles, knees, and shoulders tend to be stretched over their limit causing an injury. Like most athletes, badminton players will continue through any pain until it

becomes too strong. Both injuries and a lack of improvement can end a player's season quickly. That is where Step Up comes in.

Step Up is designed to monitor a player's movement to track improvement and mitigate the risk of injury. This is done by having a suit that is tracked by a camera which records the movement of a player. The suit places sensors on the player's joints providing equal attention to each joint. These sensors can track heart rate, speed, and rotation all connecting to the camera through Bluetooth. The data gathered creates a live digital skeleton of the player which the coach can use during practice. Providing a deeper understanding of the player's stamina, speed, power, and technic. With this data it will track a player's improvement and notify if there is THE RISK of an injury. That way adjustment can be made on the spot to optimize practice time. This helps players improve their skills faster and mitigate the risk of injury which allows them to enjoy the full length of their season.

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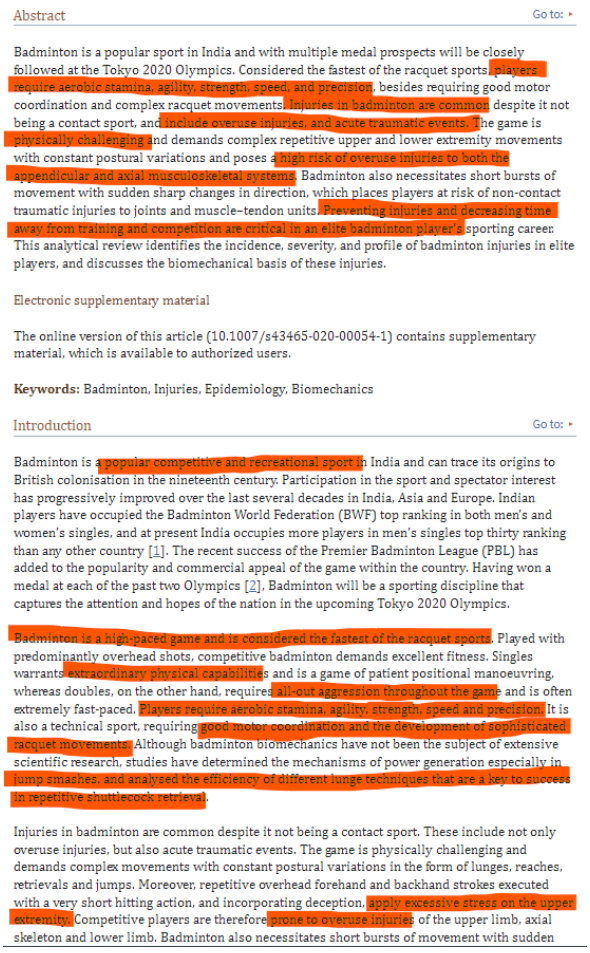
Appendix A – Discovery

The discovery of badminton injuries and the high risk of them was through multiple articles. It was unexpected the severity of injuries for a sport that is not aggressive. Even some that would seem minor to the average person could end a player's season. The main article that started further study into badminton was "*Badminton Injuries in Elite Athletes: A Review of Epidemiology and Biomechanics*" by Dinshaw N. Pardiwala, Kushalappa Subbiah, Nandan Rao, and Rahul Modi.



Abstract Go to:

Badminton is a popular sport in India and with multiple medal prospects will be closely followed at the Tokyo 2020 Olympics. Considered the fastest of the racquet sports, players require aerobic stamina, agility, strength, speed, and precision, besides requiring good motor coordination and complex racquet movements. Injuries in badminton are common despite it not being a contact sport, and include overuse injuries, and acute traumatic events. The game is physically challenging and demands complex repetitive upper and lower extremity movements with constant postural variations and poses a high risk of overuse injuries to both the appendicular and axial musculoskeletal systems. Badminton also necessitates short bursts of movement with sudden sharp changes in direction, which places players at risk of non-contact traumatic injuries to joints and muscle–tendon units. Preventing injuries and decreasing time away from training and competition are critical in an elite badminton player's sporting career. This analytical review identifies the incidence, severity, and profile of badminton injuries in elite players, and discusses the biomechanical basis of these injuries.

Electronic supplementary material

The online version of this article (10.1007/s43465-020-00054-1) contains supplementary material, which is available to authorized users.

Keywords: Badminton, Injuries, Epidemiology, Biomechanics

Introduction Go to:

Badminton is a popular competitive and recreational sport in India and can trace its origins to British colonisation in the nineteenth century. Participation in the sport and spectator interest has progressively improved over the last several decades in India, Asia and Europe. Indian players have occupied the Badminton World Federation (BWF) top ranking in both men's and women's singles, and at present India occupies more players in men's singles top thirty ranking than any other country [1]. The recent success of the Premier Badminton League (PBL) has added to the popularity and commercial appeal of the game within the country. Having won a medal at each of the past two Olympics [2], Badminton will be a sporting discipline that captures the attention and hopes of the nation in the upcoming Tokyo 2020 Olympics.

Badminton is a high-paced game and is considered the fastest of the racquet sports. Played with predominantly overhead shots, competitive badminton demands excellent fitness. Singles warrants extraordinary physical capabilities and is a game of patient positional manoeuvring, whereas doubles, on the other hand, requires all-out aggression throughout the game and is often extremely fast-paced. Players require aerobic stamina, agility, strength, speed and precision. It is also a technical sport, requiring good motor coordination and the development of sophisticated racquet movements. Although badminton biomechanics have not been the subject of extensive scientific research, studies have determined the mechanisms of power generation especially in jump smashes, and analysed the efficiency of different lunge techniques that are a key to success in repetitive shuttlecock retrieval.

Injuries in badminton are common despite it not being a contact sport. These include not only overuse injuries, but also acute traumatic events. The game is physically challenging and demands complex movements with constant postural variations in the form of lunges, reaches, retrievals and jumps. Moreover, repetitive overhead forehand and backhand strokes executed with a very short hitting action, and incorporating deception, apply excessive stress on the upper extremity. Competitive players are therefore prone to overuse injuries of the upper limb, axial skeleton and lower limb. Badminton also necessitates short bursts of movement with sudden

Figure A - DISCOVERY EXAMPLE

Summary:

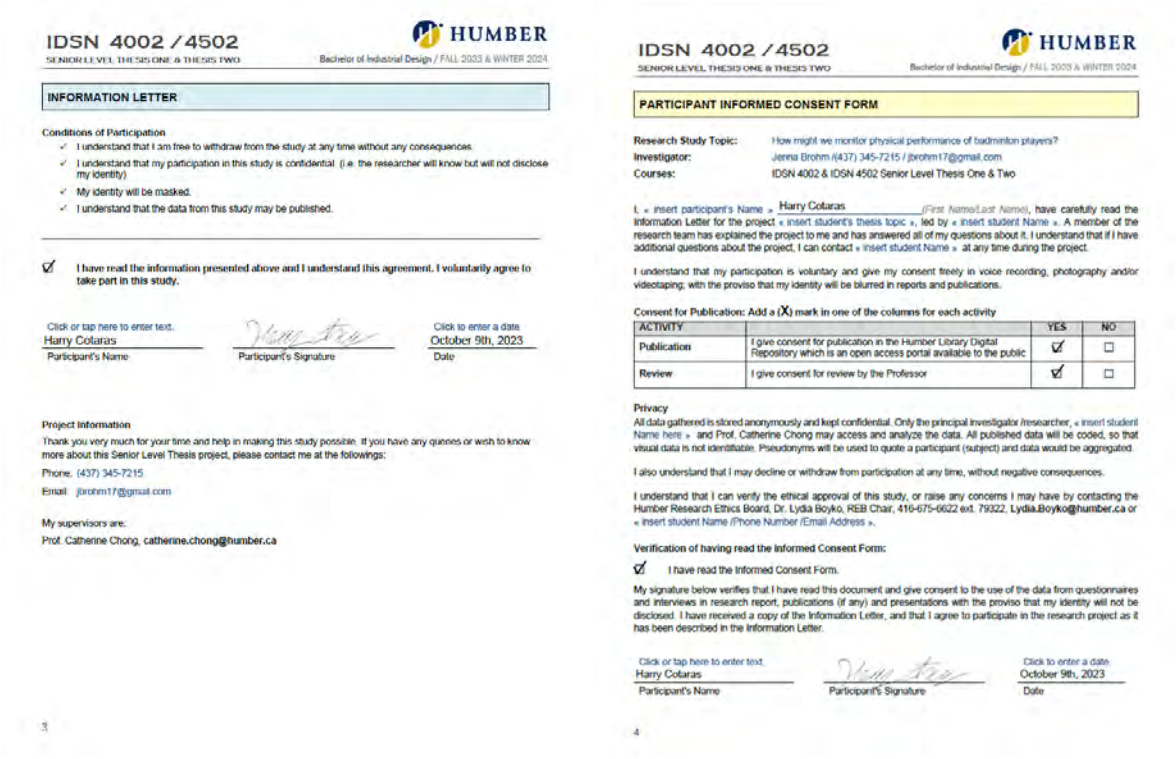
Badminton is considered the fastest racket sport in the world. It requires aerobic stamina, agility, strength, speed, and precision. Injuries are quite common considering it is a non-contact sport. These injuries are caused by overuse of the body specifically due to repetitive movement, quick changes in direction, and twisting of the joints. The most common injuries are sprains and strains, which cause muscle tension that can over-stretch making the muscle swell. Any time away from practice can quickly end the career of an elite player.

Further research was required to get a better understanding of how these injuries affect the players. This piqued the interest in how players at different levels were effected by injury, if it was bad for them. What methods were being used to prevent or mitigate injuries. A better understanding of the players and coaches was required.

APPENDIX B – CONTEXTUAL RESEARCH (USER)

To start the contextual research, players were interviewed and user observation was done during a competitions.

Two players were interviewed, one was a former badminton player and the other an intermediate player.



IDSN 4002 / 4502
SENIOR LEVEL THESIS ONE & THESIS TWO
HUMBER
Bachelor of Industrial Design / FALL 2023 & WINTER 2024

INFORMATION LETTER

Conditions of Participation
- ✓ I understand that I am free to withdraw from the study at any time without any consequences.
- ✓ I understand that my participation in this study is confidential (i.e. the researcher will know but will not disclose my identity)
- ✓ My identity will be masked.
- ✓ I understand that the data from this study may be published.

☑ I have read the information presented above and I understand this agreement. I voluntarily agree to take part in this study.

Click or tap here to enter text. Harry Cotaras — Participant's Name
Participant's Signature
Click to enter a date. October 9th, 2023 — Date

Project Information
Thank you very much for your time and help in making this study possible. If you have any queries or wish to know more about this Senior Level Thesis project, please contact me at the followings:
Phone: (437) 345-7215
Email: jbrohm17@gmail.com

My supervisors are:
Prof. Catherine Chong, catherine.chong@humber.ca

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Bachelor of Industrial Design / FALL 2023 & WINTER 2024

PARTICIPANT INFORMED CONSENT FORM

Research Study Topic: How might we monitor physical performance of badminton players?
Investigator: Jenna Brohm /(437) 345-7215 / jbrohm17@gmail.com
Courses: IDSN 4002 & IDSN 4502 Senior Level Thesis One & Two

I, « insert participant's Name » Harry Cotaras (First Name/Last Name), have carefully read the Information Letter for the project « insert student's thesis topic », led by « insert student Name ». A member of the research team has explained the project to me and has answered all of my questions about it. I understand that if I have additional questions about the project, I can contact « insert student Name » at any time during the project.

I understand that my participation is voluntary and give my consent freely in voice recording, photography and/or videotaping; with the proviso that my identity will be blurred in reports and publications.

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Review	I give consent for review by the Professor	☑	☐

Privacy
All data gathered is stored anonymously and kept confidential. Only the principal investigator /researcher, « insert student Name here » and Prof. Catherine Chong may access and analyze the data. All published data will be coded, so that visual data is not identifiable. Pseudonyms will be used to quote a participant (subject) and data would be aggregated.

I also understand that I may decline or withdraw from participation at any time, without negative consequences.

I understand that I can verify the ethical approval of this study, or raise any concerns I may have by contacting the Humber Research Ethics Board, Dr. Lydia Boyko, REB Chair, 416-675-6622 ext. 79322, Lydia.Boyko@humber.ca or « insert student Name /Phone Number /Email Address ».

Verification of having read the Informed Consent Form:

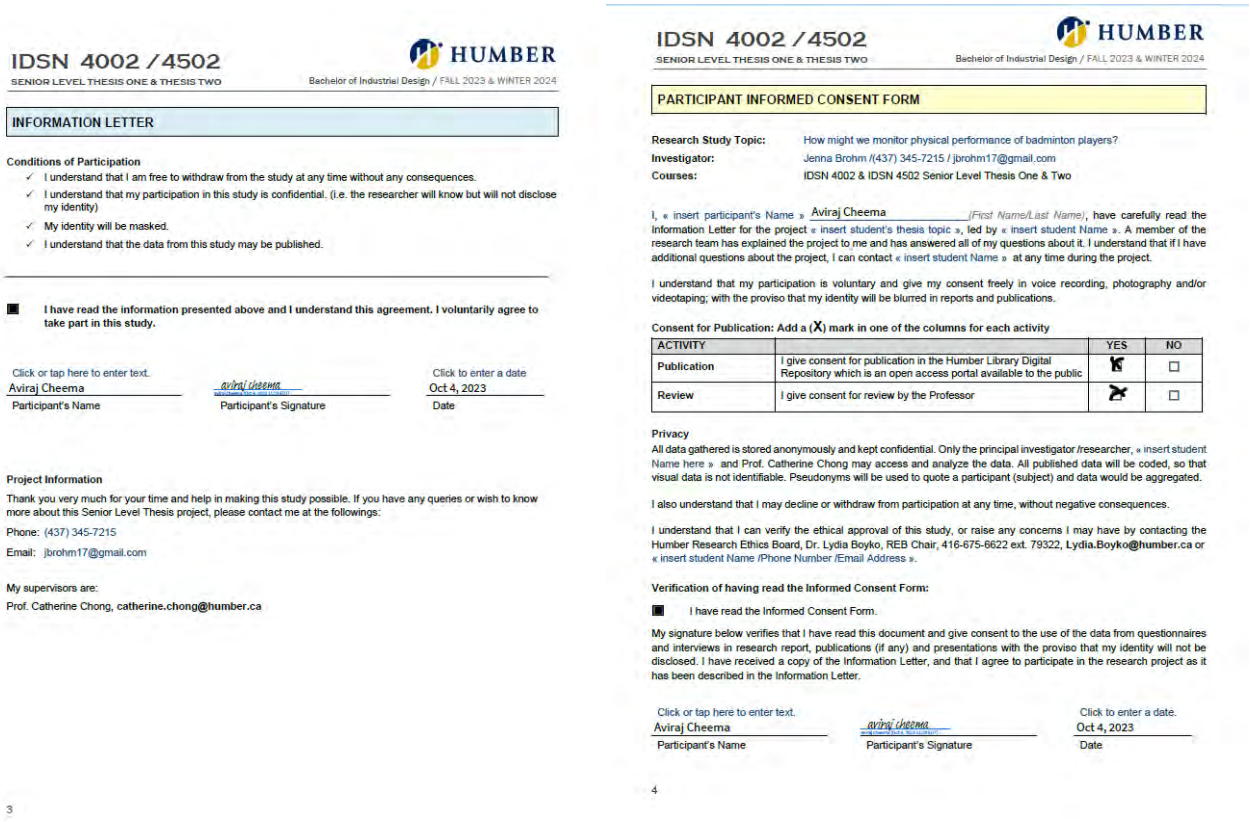
☑ I have read the Informed Consent Form.

My signature below verifies that I have read this document and give consent to the use of the data from questionnaires and interviews in research report, publications (if any) and presentations with the proviso that my identity will not be disclosed. I have received a copy of the Information Letter, and that I agree to participate in the research project as it has been described in the Information Letter.

Click or tap here to enter text. Harry Cotaras — Participant's Name
Participant's Signature
Click to enter a date. October 9th, 2023 — Date

4

Figure B1 *- ADVISOR PAPER 1*



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INFORMATION LETTER

Conditions of Participation
- ✓ I understand that I am free to withdraw from the study at any time without any consequences.
- ✓ I understand that my participation in this study is confidential. (i.e. the researcher will know but will not disclose my identity)
- ✓ My identity will be masked.
- ✓ I understand that the data from this study may be published.

■ I have read the information presented above and I understand this agreement. I voluntarily agree to take part in this study.

Click or tap here to enter text. Aviraj Cheema — Participant's Name
aviraj cheema — Participant's Signature
Click to enter a date. Oct 4, 2023 — Date

Project Information

Thank you very much for your time and help in making this study possible. If you have any queries or wish to know more about this Senior Level Thesis project, please contact me at the followings:

Phone: (437) 345-7215
Email: jbrohm17@gmail.com

My supervisors are:
Prof. Catherine Chong, catherine.chong@humber.ca

3

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PARTICIPANT INFORMED CONSENT FORM

Research Study Topic: How might we monitor physical performance of badminton players?
Investigator: Jenna Brohm /(437) 345-7215 / jbrohm17@gmail.com
Courses: IDSN 4002 & IDSN 4502 Senior Level Thesis One & Two

I, « insert participant's Name » Aviraj Cheema (First Name/Last Name), have carefully read the Information Letter for the project « insert student's thesis topic », led by « insert student Name ». A member of the research team has explained the project to me and has answered all of my questions about it. I understand that if I have additional questions about the project, I can contact « insert student Name » at any time during the project.

I understand that my participation is voluntary and give my consent freely in voice recording, photography and/or videotaping; with the proviso that my identity will be blurred in reports and publications.

Consent for Publication: Add a (X) mark in one of the columns for each activity

ACTIVITY		YES	NO
Publication	I give consent for publication in the Humber Library Digital Repository which is an open access portal available to the public	X	☐
Review	I give consent for review by the Professor	X	☐

Privacy
All data gathered is stored anonymously and kept confidential. Only the principal investigator /researcher, « insert student Name here » and Prof. Catherine Chong may access and analyze the data. All published data will be coded, so that visual data is not identifiable. Pseudonyms will be used to quote a participant (subject) and data would be aggregated.

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Verification of having read the Informed Consent Form:

■ I have read the Informed Consent Form.

My signature below verifies that I have read this document and give consent to the use of the data from questionnaires and interviews in research report, publications (if any) and presentations with the proviso that my identity will not be disclosed. I have received a copy of the Information Letter, and that I agree to participate in the research project as it has been described in the Information Letter.

Click or tap here to enter text. Aviraj Cheema — Participant's Name
aviraj cheema — Participant's Signature
Click to enter a date. Oct 4, 2023 — Date

4

Figure B2 - *ADVISOR PAPER 2*

Method:

Questions were prepared prior to the interviews, both being asked the same questions. The desired outcome was to get a better understanding of badminton players and the challenges they face. Interviews were held over the phone and recorded so they could be reviewed at a later date. The questions are in the colum to left and the two sets of answers are in the two colums to the right.

Questions	Interviewee: Former Badminton Player	Interviewee: Intermediate Badminton Player
When playing Badminton what is your daily life like?: Are you working? Is a lot of time dedicated to Badminton?	When competing four times on court. there were also off court actives. it can be encompassing, on court and off court time. to remain flexible. can be time consuming expecially with school. it definetly took up time.	I have practice 2-3 times a week. I am an industrial design in Midland. I go afterwork. We work on communication and technicals. we have compotitions 2-3 times a year.
What is your experience with Badminton?	Started later, I started when I was 12 to when covid start. in 2017 I was playing competitivly. I spent time in Denmark where badminton is a lot more	I got into because of my parent at 7-8. I am good at hand-eye coordination sports. i played

	common. Denmark has the strongest players. Humber I played on the varsity team. I won a few awards. I never made it to nationals, I had a hard time mentally. I don't play now due to the changes in my life.	throughout school. it is an experience that i continue to grow. it is a hobby i cant seem to leave.
What would you say are your main needs/desires as a player?	The needs were to keep healthy and physically fit. it is physically demanding and fast pace. the need to stay arobically fit and muscle strength to move around courts. Badminton has a large court where you need to move to all 4 courners. if your footwork isn't there you use more energy. the hand eye corodiation.	I need more practice time, it isn't easy to cover everything in 2-3 sessions a week. i feel i should be practicing everyday. i wish equipemnt wasn't so expensive. shoes are also very expensive, i don't need braces. my knees are ok. i wish braces were either multi-functional or cheaper. finding the proper racket is expensive. they can cost $200 for a good one. i would love to have a bag that could carry all my equipment but not be so big.
What are the main challenges you notice in Badminton?	Physical ability, the proper footwork, proper arm swing, and the mental self. specifically in singles, doubles needs a lot of communication. the first challenges are fundametal skills for younger ages. injuries as well, when I was younger I injured by lower back. Common injuries are shoulder, wrist, knee, ankle, back, muscle soreness, overuse of muscles.	First is developing that hand-eye coordination. control is also important and the correct amount of power. you need constant stamina, communication with your partner. you need a [artner that knows where you are on the court. maintaining your body is difficult, it is easier for professionals. maintaining all the equipment. it is staying with the trends in a way, there are always new rules. there is a referee specially for how you serve a shuttlecock. maintaining a schedule with playing is hard to find. the environment, the courts are not always professional grade. gym floors for example are a lot harder. wrist is one of the biggest challenges I have ever faced, it is all about practice in the end.
What is some of your favorite equipment to use?	Main global player is yonex, they also do tennis. the top players tend to use this brand. same with shoes, more targeted to badminton and shock absorbusion. the main shapes are hexagons for more official movement. yonex has the strongest shoes. Victor is another brand, retty big. Li-ing is a multi sport brand. A danish one FZforza is a bit smaller, but this have international players using it. Black Night is a North American brand. they do badminton and squash. smaller brand and only in North America. some of their equipment is for training. they have a shuttlecock shooter. they have a tool that helps with your footwork, this is adjustable to where you want to focus your work. younger age might need to wear eye-googles. i had to wear them to protect my eyes when i was younger. Black Knight is good for training.	I prefer Yonex, they are the best. i have had one for 7 years and re-strung it 8 times. some prefer heavier weights other prefer lightweight. i like lightweight, they are better for agility. yonex shoes are really good as well. sweat proof clothing is really good to. for practice we use plastic birdies (shuttlecocks) abd for competition we use the real ones. the one i use is from the Voldrids by yonex. it also depensed on the strings you use. there is metal strings, they provide more power and can be hard to control. they provide power, control, and durability. if you are the player i am you want more control and durability. each racket has a triangle on the end cap that has different ratings to give you more information. it all depends on the players.
Please explain your communication with your coach and other players.	Between a coach is very important, you would have 1-2 coaches behind the court giving. the scoring system is best 2/3 to 21 points. you take a break at 11 points. the coach can give you feedback during this break or afterwards. you need	I haven't had a coach since college, communication with them is critical. during games they are the key communicating person. they watch the player to tell they what to improve and how they can beat their opponent. for doubles

	to believe in them the same amount they believe in ou. same with partners, being able to communicate on court. cheering each other on and giving some feedback. adjusting together when they notice any advantage.	communication is really important. they do a specific rotation to cover more ground. this takes years to do.
Have you ever been injured? What is your experience with the medical team?	I went to physical therapy for my lower back. a disc was out of position, the muscles seesd up to protect the joint. you have to strengthen your core muscles to prevent that injury in the future. it was hard and frustarating being unable to practice. that is what happens when you play proffessionally.	We never had a medical team. i had 2 major injuries. most recent was a nerve that goes from your shoulder to your hand and makes it go numb. it was caused by desk job, the habit i had of resting my elbows on the desk. this caused me to rest for a few weeks. it was mostly smashing that caused a nerve shock in my shoulder. the second injury was in high school and i shattered by shin bone. i swung my leg around and it hit the net post. i thought it was just sore and didn't go to the doctor for a few months. i had a 3 inch break in my shin. if i run for too long i can feel a bit of that pain come back.
How do you find monitoring your improvement as a player?	You could video record yourself playing. you would have training partners and coaches that would monitor your play. you could do some internal monitoring. in tournaments you can monitor yourself.	It is really hard. you don't know if you improved until you played against better players. i only ever got to intermediate level. if you beat someone above you in a game 2/3 then you would move up. there would be cones that you had to hit in order to tell if you have gotten better. either you or your coach have to monitor you.
Do you train for Badminton? What are your main training technics?	I would focused a lot on footwork, it was my main focus. I wasn't very good at controlling the shuttle. I could move the shuttle but not as prefectly as one should be.	We practice 3 times a week. training depends on the sesion. some days are about game play, how to break someone's defense, build up stamina (6-7 games in a row). stamina and indurance is very important. the coach is telling you what feels right, like you don't want to do a back hand shot.

Table B - INTERVIEW RESULTS

In Summary:

Badminton took up a lot of time for both players due to competitions and training. They both started playing badminton as children, but their passion for the sport grew with them. Throughout their experience with badminton the physical aspect of the sport is the most important. Footwork, hand-eye coordination, muscle control, and reflexes being the most desired abilities. The biggest challenge was maintaining these skills, as well as the mental aspect associated with them. Joints and the lower back were difficult for both players to control. Both players suffered from injuries either caused by badminton or

interfering with their ability to play. It was very upsetting since they had to miss games which slowly lowered their skill level. Communication is very important whether it is with a double's player or your coach. Coaches would monitor the match looking for weaknesses in the opponent. However, there are only two opportunities to talk with the coach, halftime and after the match. All these aspects were considered as Step Up developed.


PANEL ON RESEARCH ETHICS
Navigating the ethics of human research

TCPS 2: CORE 2022

Certificate of Completion

This document certifies that

Jenna Brohm

successfully completed the Course on Research Ethics based on the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS 2: CORE 2022)

Certificate # 0000953203

13 September, 2023

Figure B3 - *ETHICAL CODUCT FOR RESEARCH*

User Profile

Primary Users: Badminton Players and Coaches.

Most players start as children and will continue their badminton career into their early forties. However, due to injuries this is more for those that play recreationally. Coaches were badminton players previously or continue to play.

Jenna Brohm

Gender and ethnicity are equal as badminton is played all over the world. Although, it is more popular in countries like Denmark, India, and China. Players tend to practice at least 3 times a week to daily, depending on their level of skill. There is no specific amount of income required to play, however equipment and location can be expensive. Any level of education is fine for a player, a coach would have to study physical fitness and health to some extent.

Secondary: Medical Team

Media teams are only present at competitions and look over the player before a match. They are not present during training and are only accessible to professionals.

Tertiary: Badminton Equipment Company

Sponsors are the tertiary users to help improve the sport. Anything learned about being able to monitor a player's physical performance will help develop a company's products.

Activity Mapping

	Arrive at Court/Gym	Warm Up	Playing	Breaks	Cool Down	Return Home
User Goals	1. Change into athletic wear 2. Fill water bottles 3. Look over their equipment	1. Stretch muscles 2. Participate in training activities 3. Practice shots and movements	1. Moving quickly across the court 2. Having power behind shots 3. Shooting to multiple areas of the opponent's side of the court	1. Re-hydrating 2. Quick stretches 3. Relaxing 4. Sitting down 5. Massaging muscles	1. Stretch muscles 2. Yoga exercises 3. Breathing exercises	1. Rest 2. Have a cool shower 3. Massage any stiff muscles
Problems/Challenges	1. Not wearing the correct apparel	1. Not stretching before the game 2. Training is not	1. Not holding the racket correctly 2. Falling/sliding	1. Having little break time between matches	1. Skipping this part	2.

		focusing on their specific needs	3. Overusing their body	2. Not re-hydrating 3. Not using that time to relax		
Takeaways	1. Players need breathable clothing and proper shoes	1. This needs to work for multiple people 2. It needs to be adjustable	1. This is when people will overuse their body 2. Monitoring will be critical during this part 3. Highest risk of injury	1. This is the most common time to talk with a coach 2. This time can vary depending on times allowed	1. People might skip this 2. Similar to training, it must be adjustable 3. Skipping leads to a greater chance of injury	1. This helps calm the muscles down 2. Injuries will be noticed here or the next day 3. Depending activities after this injuries, like in the shoulder, are likely to be ignored
Feelings	1. Calm 2. Excited	1. Excited	1. Highest heart rate 2. Focusing on the game, not their body	1. Tired 2. Excited for the next game	1. Tired 2. Wants to go home	1. Tired 2. Relaxing 3. Proud

Table B2 *- ACTIVITY MAPPING*

Summary:

Players need flexible and breathable clothing to move easily around the court. They always participate in warm up / training before the game starts. However, cool down which helps to relax the muscles after a game is often skipped. With the limited time players must speak with their coach there will need to be live data gathered.

APPENDIX C – FIELD RESEARCH (PRODUCT)

Product benchmarking allowed a better understanding of what players and coaches already had access to. This helped by providing features, materials, and manufacturing processes that players preferred. It also showed what has not worked and ideas never touched upon. This helped to explore new ideas to benefit both players and coaches. The main products on the market are listed in the table below.

Product List

Products	Examples	Positives	Negatives
Smartwatches	• Amazfit T-Rex 2 • Polar Vantage M2 • Garmin Forerunner 245M	• Lightweight • Live data • Some have built-in sports profiles • Touch-screen and button options • Monitors heart rate, calories burned, etc.	• Data accessed through a phone • Can be expensive • Data gathered is too general
Accessories	Usense	Comes with an app	• Adds weight to racket • Only has data related to racket movement
Training Equipment	SD55 Quiver	• Helps with speed training • Holds 55 shuttlecocks	• No longer available
	SD200 Shadow Trainer	• Advanced training • Good for all levels of player • Increases reaction time and speed	• Only one player can use it at a time • Doesn't track movement
	Forearm Trainer	• Increase strength in forearms and fingers • Weight is adjustable	• Only for training • Not used in practices
	Minibands	• Helps with injury prevention • Improves leg axis • Increases shoulder mobility • Multiple exercises can be done	• Only helps with training • Cannot be used during a practice game
	Balance Pad	• Improves ankle stability • Improves balance • Helps with landing	• Difficult to track improvement past a certain point

Coaching Software	• Dartfish • Baddy Pro • Hudi	• Provides video analysis • Some a free • Allows for slow motion review after a game	• High risk of freezing • Can be expensive • Provides same benefits as smartphone camera

Table C - PRODUCT LIST

Summary:

There is nothing on the market that can provide tracking of the player. Most products focus more on following the game than the player. The training equipment helps prepare the body but does not monitor the individual's needs. These products are helpful to an extent, but they need data to better understand how to help an individual.

APPENDIX D – RESULT ANALYSIS

User Needs:

The main need of both player and coach is to get a better understanding of how the body moves. This will provide the information necessary to monitor the physical performance of a player. Which will show if the player is improving and at what rate. At the same time, showing any areas at risk of injury. Their training can then be adjusted to continue that growth and/or counter any challenges due to injury.

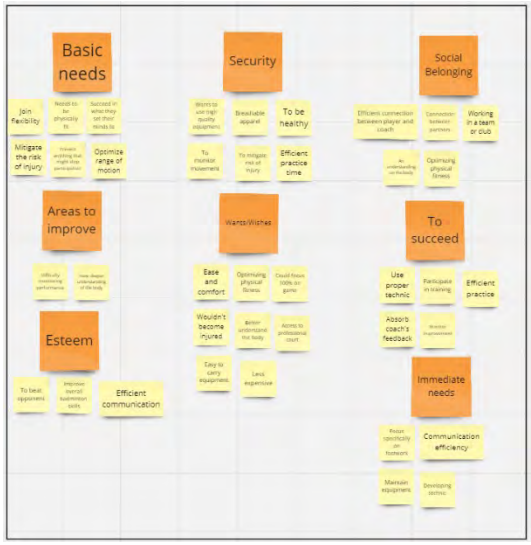

Figure D71 - USER NEEDS

Summary:

Basic needs are to mitigate the risk of injury. Helping players to be physically fit while optimizing range of motion.

Security is to make efficient use of the practice time allowed. To help players be healthy and not put their health at risk.

Wants and wishes are to help players improve their skills. Their main goal is to enjoy the game and do well. That is the reason they started playing badminton in the first place.

Jenna Brohm

Figure 72 - PRIORITY OF NEEDS

Summary:

The priorities are to optimize physical fitness and mitigate the risk of injury. To do this, a player's skill must improve. Specifically in technical and tactical.

Needs Statement:

The badminton player needs assistance in monitoring their physical health because this is a difficult sport. Seeing improvement is their motivation to do even better. Badminton is also a social activity as a player must work well and have efficient communication with their coach and teammates. Esteem ca be achieved by using high quality equipment to improve one's badminton skills. Control and mastery of the sport is related to being able to monitor one's performance on the court.

APPENDIX J – APPROVALS & PLANS

IDSN 4002/4502
SENIOR LEVEL THESIS ONE AND TWO

Humber ITAL / Faculty of Media & Creative Arts
Bachelor of Industrial Design / FALL 2023
Catherine Chong

FTA-2 (B) THESIS TOPIC APPROVAL (Preliminary Abstract)

THESIS TOPIC APPROVAL:

Student Name:	Jenna Brohm
Topic / Problem Definition:	How Might We Monitor Physical Performance of Badminton Players?

TOPIC DESCRIPTIVE SUMMARY (PRELIMINARY ABSTRACT)

Badminton players are prone to injuries and unable to monitor their own movements which makes it difficult playing to their full potential. A research study by Kaldau done in 2021 focusing on elite junior players at the World Junior Championship in 2018, found that seventy-four players had at least one severe injury. Most common injuries were in the lower extremities, specifically the ankles, knees, and lower back. *Injuries in Badminton, A Review* by Phomsoupha and Laffaye in 2020 discovered that these injuries are caused by direction changes, jumps, lunges, and rapid arm movements. Players tend to play through any pain, making injuries worse and have little opportunity to receive feedback from their coach. The purpose of this thesis is to do an in-depth study of badminton players' movement for a deeper look into their overall performance. Using interviews, observations, and product benchmarking for data collection will build a detailed analysis. Evaluating ergonomics by having discussions with advisors, calculating speed and force behind certain movements, and comparing to equipment currently on the market. Focusing on training methods and what areas of the body receive the most attention will narrow the amount that needs to be monitored. Due to the lack of solutions that monitor the movement of a player during a game to improve their play and mitigate the risk of injury. Providing a deeper understanding of how a player's game can improve. While reducing the risk of injuries to the player. This will lead to a solution that will improve the physical performance of badminton players.

Student Signature: Jenna Brohm	**Instructor Signature:** Catherine Chong
Date: 06/10/2023.	**Date:** 12 October 2023

Chong, Keppie

Figure J173 - THESIS TOPIC APPROVAL


PANEL ON RESEARCH ETHICS
Navigating the ethics of human research

TCPS 2: CORE 2022

Certificate of Completion

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Jenna Brohm

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Certificate # 0000953203

13 September, 2023

Figure J2 - TCPS 2 CERTIFICATION OF COMPLETION

Introduction

The purpose of this thesis is to look at the challenges that badminton players and their coaches face. This will allow an in-depth study with hopes of finding a valuable solution. It requires a search to see the common activities of badminton players and different training methods. Need to see what products they have available to them and if they solve certain problems. This information will be gathered in a variety of ways. Below explain the research and methods used to get specific information.

Research Plans:

User Profile	To understand the average badminton player or coach and what activities they participate in.
User Observation	How do players and coaches act daily. What is done to get ready for a game, what training is used, and what is done after a game? This will show any common occurrences that could or do lead to challenges.
Current User Behaviour	This is to show how players or coaches react during certain situations. Behaviour will change depending on the situation. This could indicate problems that relate to the challenge.
Current Product/s Used	What products are commonly used and for what reasons. This should indicate things that work well for players and things that don't.
Activity Mapping and Journey Mapping	This is to map out the journey of specific scenarios and how a player reacts to them. Does anything change and how does the player feel afterward. The same goes for the coach.
Product Benchmarking	What products do players and coaches currently have access to. What is helpful and what is not? How do these products help the player and/or coach.

Table J1 - RESEARCH PLANS

Research Sources / Methods

- Interviews with Badminton Players
- Articles related to Badminton Challenges
- Literature Research
- Video Analysis

Interview Questions

When playing Badminton what is your daily life like?: Are you working? Is a lot of time dedicated to Badminton?
What is your experience with Badminton?
What would you say are your main needs/desires as a player?
What are the main challenges you notice in Badminton?
What is some of your favorite equipment to use?
Please explain your communication with your coach and other players.

Have you ever been injured? What is your experience with the medical team?
How do you find monitoring your improvement as a player?
Do you train for Badminton? What are your main training technics?

Table J2 - INTERVIEW QUESTIONS

Advisor Initiatives

The advisors were contacted multiple times throughout the design process.

Interview 1: September 11, 2023. To discuss the main challenges for a badminton player. This was done in-person and was an hour long.

Interview 2: September 20, 2023. To discuss the main challenges for a badminton player. This is with a person on a different level. This was done over the phone and was an hour long.

Interview 3 and 4: October 31, 2023. Run a few ideas by them. Ask for feedback based on some ideas.

Project Timeline

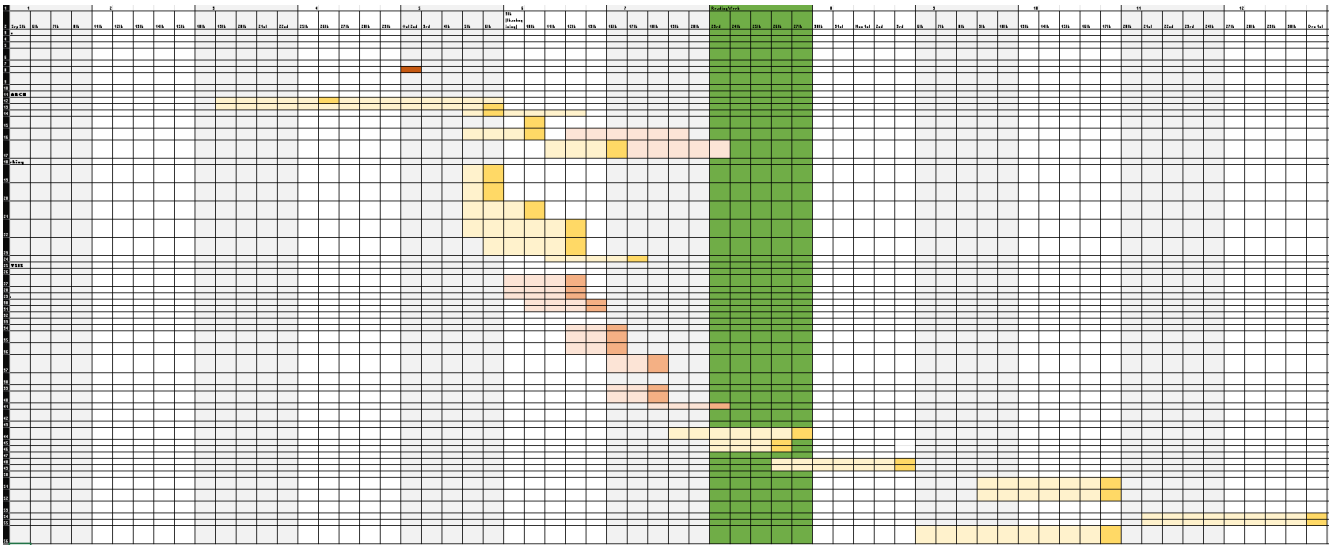


Figure J3 - PROJECT TIMELINE FALL

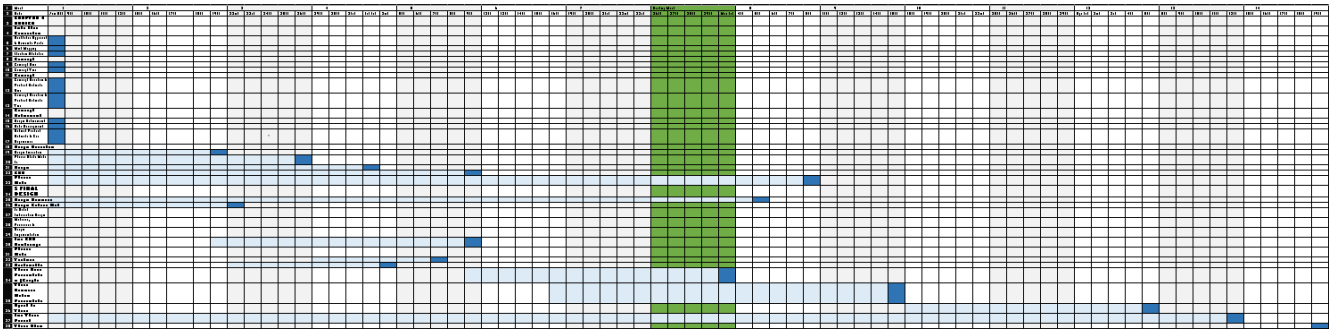
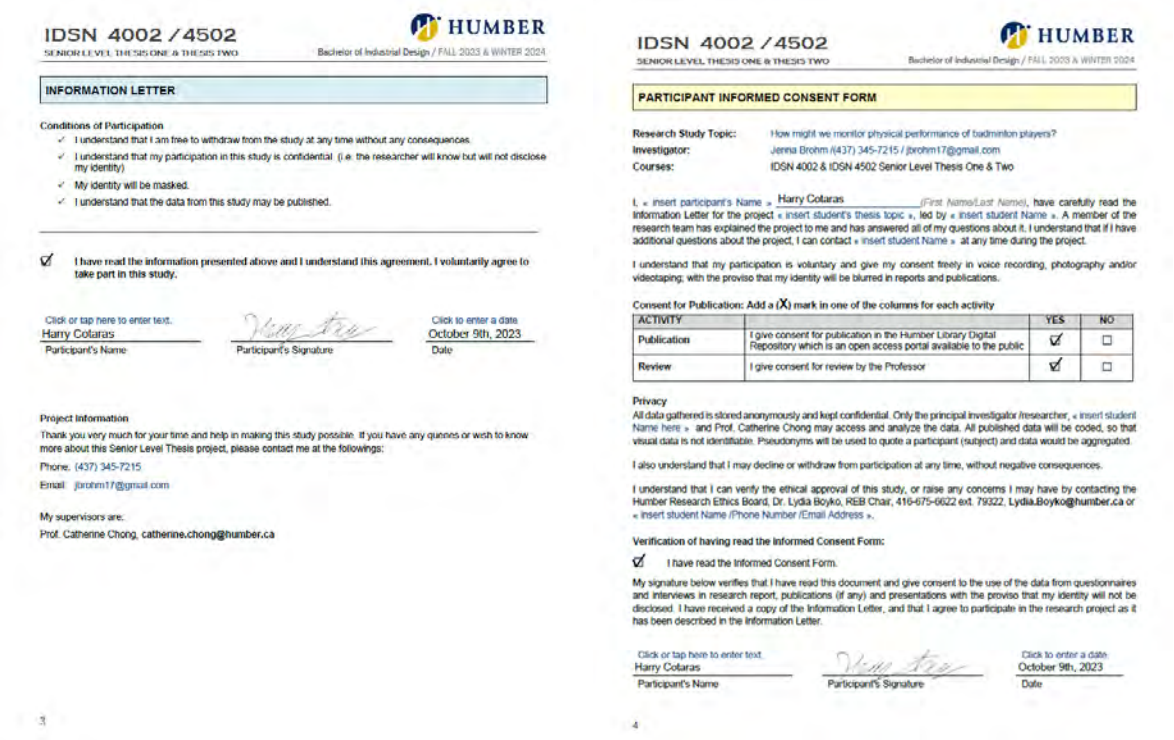


Figure J4 - PROJECT TIMELINE WINTER

APPENDIX K – ADVISOR MEETINGS & AGREEMENT FORMS



IDSN 4002 / 4502
SENIOR LEVEL THESIS ONE & THESIS TWO
HUMBER
Bachelor of Industrial Design / FALL 2023 & WINTER 2024

INFORMATION LETTER

Conditions of Participation

- ✓ I understand that I am free to withdraw from the study at any time without any consequences.
- ✓ I understand that my participation in this study is confidential (i.e. the researcher will know but will not disclose my identity)
- ✓ My identity will be masked.
- ✓ I understand that the data from this study may be published.

☑ I have read the information presented above and I understand this agreement. I voluntarily agree to take part in this study.

Click or tap here to enter text. Harry Cotaras — Participant's Name
Participant's Signature
Click to enter a date. October 9th, 2023 — Date

Project Information

Thank you very much for your time and help in making this study possible. If you have any queries or wish to know more about this Senior Level Thesis project, please contact me at the followings:

Phone: (437) 345-7215
Email: jbrohm17@gmail.com

My supervisors are:
Prof. Catherine Chong, catherine.chong@humber.ca

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HUMBER
Bachelor of Industrial Design / FALL 2023 & WINTER 2024

PARTICIPANT INFORMED CONSENT FORM

Research Study Topic: How might we monitor physical performance of badminton players?
Investigator: Jenna Brohm /(437) 345-7215 / jbrohm17@gmail.com
Courses: IDSN 4002 & IDSN 4502 Senior Level Thesis One & Two

I, « insert participant's Name » Harry Cotaras (First Name/Last Name), have carefully read the information Letter for the project « insert student's thesis topic », led by « insert student Name ». A member of the research team has explained the project to me and has answered all of my questions about it. I understand that if I have additional questions about the project, I can contact « insert student Name » at any time during the project.

I understand that my participation is voluntary and give my consent freely in voice recording, photography and/or videotaping; with the proviso that my identity will be blurred in reports and publications.

Consent for Publication: Add a (X) mark in one of the columns for each activity

ACTIVITY		YES	NO
Publication	I give consent for publication in the Humber Library Digital Repository which is an open access portal available to the public	☑	☐
Review	I give consent for review by the Professor	☑	☐

Privacy

All data gathered is stored anonymously and kept confidential. Only the principal investigator /researcher, « insert student Name here » and Prof. Catherine Chong may access and analyze the data. All published data will be coded, so that visual data is not identifiable. Pseudonyms will be used to quote a participant (subject) and data would be aggregated.

I also understand that I may decline or withdraw from participation at any time, without negative consequences.

I understand that I can verify the ethical approval of this study, or raise any concerns I may have by contacting the Humber Research Ethics Board, Dr. Lydia Boyko, REB Chair, 416-675-6622 ext. 79322, Lydia.Boyko@humber.ca or « insert student Name /Phone Number /Email Address ».

Verification of having read the Informed Consent Form:

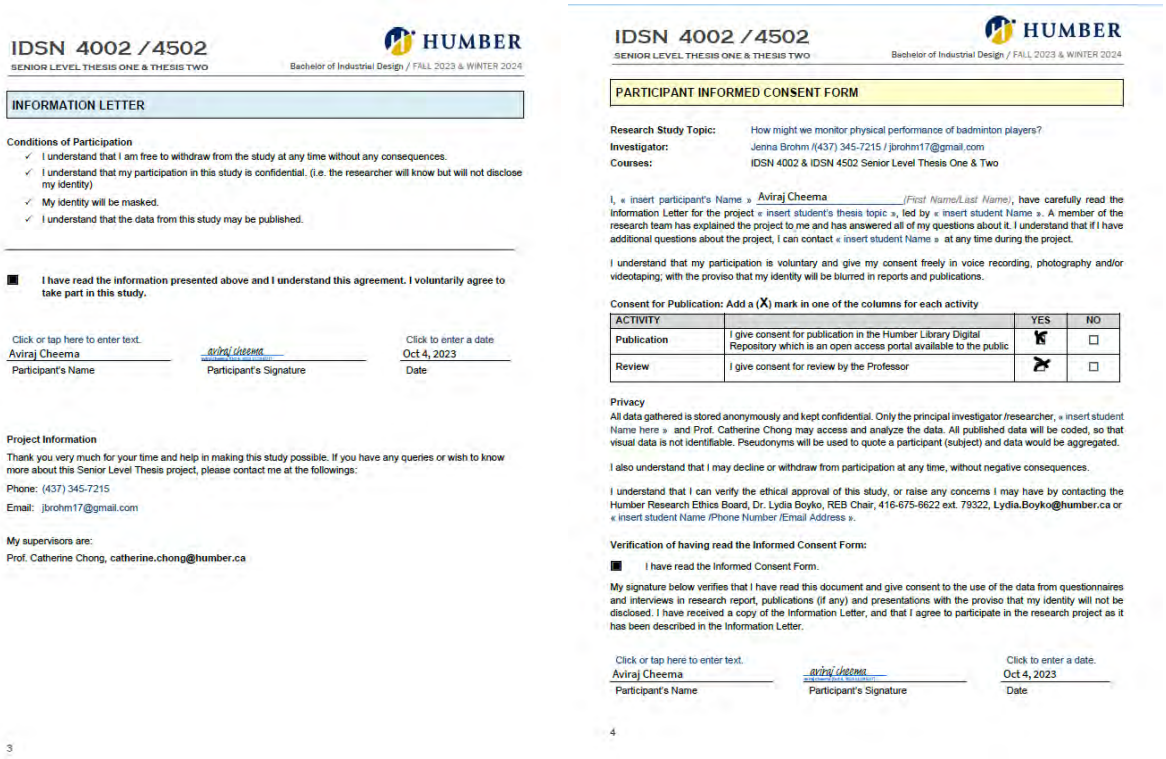
☑ I have read the Informed Consent Form.

My signature below verifies that I have read this document and give consent to the use of the data from questionnaires and interviews in research report, publications (if any) and presentations with the proviso that my identity will not be disclosed. I have received a copy of the Information Letter, and that I agree to participate in the research project as it has been described in the Information Letter.

Click or tap here to enter text. Harry Cotaras — Participant's Name
Participant's Signature
Click to enter a date. October 9th, 2023 — Date

4

Figure K1 *- ADVISOR 1 AGREEMENT FORMS*



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Bachelor of Industrial Design / FALL 2023 & WINTER 2024

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- ✓ My identity will be masked.
- ✓ I understand that the data from this study may be published.

☒ **I have read the information presented above and I understand this agreement. I voluntarily agree to take part in this study.**

Click or tap here to enter text.		Click to enter a date
Aviraj Cheema	aviraj cheema	Oct 4, 2023
Participant's Name	Participant's Signature	Date

Project Information

Thank you very much for your time and help in making this study possible. If you have any queries or wish to know more about this Senior Level Thesis project, please contact me at the followings:

Phone: (437) 345-7215

Email: jbrohm17@gmail.com

My supervisors are:

Prof. Catherine Chong, **catherine.chong@humber.ca**

3

IDSN 4002 /4502
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Investigator: Jenna Brohm /(437) 345-7215 / jbrohm17@gmail.com
Courses: IDSN 4002 & IDSN 4502 Senior Level Thesis One & Two

I, « insert participant's Name » Aviraj Cheema *(First Name/Last Name)*, have carefully read the Information Letter for the project « insert student's thesis topic », led by « insert student Name ». A member of the research team has explained the project to me and has answered all of my questions about it. I understand that if I have additional questions about the project, I can contact « insert student Name » at any time during the project.

I understand that my participation is voluntary and give my consent freely in voice recording, photography and/or videotaping; with the proviso that my identity will be blurred in reports and publications.

Consent for Publication: Add a (X) mark in one of the columns for each activity

ACTIVITY		YES	NO
Publication	I give consent for publication in the Humber Library Digital Repository which is an open access portal available to the public	X	☐
Review	I give consent for review by the Professor	X	☐

Privacy

All data gathered is stored anonymously and kept confidential. Only the principal investigator /researcher, « insert student Name here » and Prof. Catherine Chong may access and analyze the data. All published data will be coded, so that visual data is not identifiable. Pseudonyms will be used to quote a participant (subject) and data would be aggregated.

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Verification of having read the Informed Consent Form:

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Click or tap here to enter text.		Click to enter a date.
Aviraj Cheema	aviraj cheema	Oct 4, 2023
Participant's Name	Participant's Signature	Date

4

Figure K2 *- ADVISOR 2 AGREEMENT FORMS*