SKADE

Developing Tomorrow's Alpine Champions

Improving Training for Young Ski Racers

Lindsey Moscoe

Improving Training for Young Ski Racers

by

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Abstract

Alpine ski racing debuted at the Olympics in 1936. Since then, there have been many changes in both equipment and training practices. Currently, skill development is achieved through verbal, visual, and kinetic communication between the coach and the racer. Verbal and visual communication are most often achieved while standing still, and kinetic communication is most often achieved through the completion of drills and repetition. Additionally, each racer requires a personalized approach to teaching. Coaches must be able to communicate effectively in order to teach specific and sometimes subtle body movements to racers. There is currently no training device that improves a racer's skills while they are skiing. The proposed product solution is based on an in-depth study of the user, how they grow, the skills they must master, and the functionality of the human body. This information was gathered through data collection, observational studies, and interviews. The solution enhances verbal and kinetic communication between coaches and racers, and will enable coaches to better train their athletes.

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1 Project Definition

This chapter defines the problem that is being addressed in this thesis. It considers different investigative approaches that aid in the accumulation of information and data that support this thesis. Additionally, it discusses the background, history, and social context of ski race training.

Figure 1. A coach gives pointers to a young racer (Broberg, 2016).

1.1 Problem Definition

This thesis proposal investigates the skills development of young alpine ski racers. The primary method of on-hill skill development is achieved through verbal communication, which can be misunderstood. Skiers are also trained with drills, which may be completed incorrectly. Non-active training is carried out through observation, which is done with the racer standing still, and video review, which happens at the end of the day when the racer is off-snow. There is currently no training device that improves a racer's skills while they are skiing. This thesis proposes an in-depth study of the user, how they grow, the skills they must master, and the functionality of the human body, through data collection, observational studies, interviews, and surveys. A detailed analysis of the evaluation process was done with the goal of minimizing the negative experiences and maximizing the positive experiences of alpine ski racers. Results from the specific studies were used to design the next generation training device for ski racers. Designing a skills training device based on ethnographic considerations will help improve the human interaction design aspects of ski racing.

1.2 Investigative Approach Taken

Several methods of research were used to gather information. The methods include:

- Literature reviews
- Information searches
- User and expert interviews
- User and expert observations

- Ergonomic studies
- Experience mapping

Information that must be collected prior to idea generation include:

- User demographics
- Target user ergonomics
- User needs

Thesis methods were used to answer the following questions:

- How can the miscommunication between coaches and racers be reduced?
- How can the skills be better taught?
- How can we keep more racers in the sport for longer?

1.3 Background/History/Social Context

The ski was invented before the wheel (Sood, 2010). Skiing began 22,000 years ago as a transportation method and a necessary means for survival in Central Asia and Europe (Sood, 2010). Skiing's next evolution came in the 1760s, when the Norwegian army held skill competitions that involved skiing down hills, around trees, across flat land, and skiing while shooting at markers (Sood, 2010). These competitions were the precursors to alpine ski racing as we know it today (Sood, 2010).

The first modern national alpine ski racing competition was held in Norway in 1868 (Alpine skiing equipment and history, n.d.). A few decades later, the sport spread to the rest of Europe and North America, where miners held ski races to entertain themselves during the

winter (Alpine skiing equipment and history, n.d.). Alpine skiing debuted at the Olympics in 1936 (Alpine skiing equipment and history, n.d.).

Today's ski racers must have muscular strength and power, balance, and agility, as ski racing demands lateral and forward-backward balance over changing terrain (Raschner, Hildebrandt, Mohr, & Müller, 2017). Balance, in particular, is affected by age and physical maturity, and affects performance and injury prevention (Raschner, Hildebrandt, Mohr, & Müller, 2017). Additionally, the risk of sustaining an injury increases during growth spurts because the body is growing and changing (Steidl-Müller, Hildebrandt, E, Fink, & Raschner, 2018).

2 Research

This chapter outlines the different research methods used thought the initial design development stage. It contains user and product research that support the product solution design. In addition, it helps develop a clearer understanding of current product solutions that are used or are available for use for ski race training, or athletics training in general. Some research methods that were used during the user research phase include benchmarking and activity mapping on current products and user experiences.

2.1 User Research

2.1.1 User Profile/Persona

Primary user: Ski racer

This thesis project focuses on racers in the U12 and U14 groups (ages 10 to 14). They are all genders. Children in this age group are going through puberty, which causes growth spurts and changes in body composition. They are beginning to build muscle, grow in height, and gain weight, which makes it difficult to continue to learn skills that require excellent balance and strength. Additionally, as the human brain does not finish developing until about 25 years of age, communication between coaches and athletes can be difficult (Understanding the teen brain, n.d.).

Secondary user: Ski coach

The secondary users are alpine ski coaches. Coaches teach racers on the hill and help them to improve their skiing skills. There is no specific age group for coaches, however one must be over the age of 16 to be allowed to complete the entry-level CSFC course.

Demographics		**User behaviour**	
Age	10-14	**Frequency**	2-6 days/week from Dec. – Apr.
Gender	All genders	**Duration**	5-7 hrs/day
Stage of life	Puberty	**Social/solidarity**	Mixed
Age (secondary)	Above 16	**Level of focus**	High
Gender (secondary)	All genders	**Location**	Hill or mountain (ski resorts)

Education (secondary)	CSFC certification	**Motivation**	Improving, winning, having fun

Persona This fictional example provides a demographic and persona summaries to show user behaviour.

NAME	**TAYLOR SMITH**
AGE	12
FIRST TIME SKIING	Age 3
FIRST RACE	Age 6
PROGRAM	
EDUCATION	Grade 7
LOCATION	Collingwood, ON
MAIN SPORT	Ski racing
FREQUENCY	Season dependent - Fall ski camps - Winter break training - Friday to Sunday training from Jan. to mid-March - Occasionally night skiing
DURATION	5 to 7 hours per training day, 2 to 4 hours of gate training/day
SOCIAL	Trains individually along with other racers that share the same coach
OTHER PURSUITS	- Basketball (school team) - Mountain biking (summer)

Figure 2. Lacie Greenwald, 12-Year-Old Hobe Sound Ski Champion (Laciegreenwald.com, 2014).

Profile

Taylor Smith is a 12-year-old from Collingwood, Ontario. They are in grade seven. Taylor's main sport is ski racing. They have been skiing since they were three and racing since

they were six. They began skiing as it was a regular family activity. Taylor fell in love with the sport and hopes to be able to race at the Olympics one day. Taylor is working on balance, strength, and getting used to their growing body with help from their coach.

User behaviour

Taylor's first training camp of the season with their team is in November. The team members enjoy each other's company while on the ski lifts. While skiing, they concentrate on doing what they have been asked to do by their coach. After a day on the hill, they gather for dryland training, which may involve running, a game of volleyball, or calisthenics. After dryland and dinner, the team gathers to tune their skis and prepare their equipment for the next day. They take very good care of their equipment, as they understand how important it is to their success. After the fall training camp, Taylor looks forward to starting regular season training and racing over the school winter break. They are motivated to train hard in order improve their race results this season.

2.1.2 Current User Practice

Frequency

Ski racers train two to six days a week from December to April. Sometimes racers also go on ski camp trips in the summer and fall.

Duration

Each training day on snow consists of one to four warm up runs, one inspection run of the training course, three to eight training runs on the course, and zero to four more runs in the course depending on the snow conditions (Hydren, Volek, Maresh, Comstock, & Kraemer, 2013). Training sessions last between two and four hours, and there are often two sessions in

one day (Hydren, Volek, Maresh, Comstock, & Kraemer, 2013). In total, each day is between five to seven hours.

Social or Solitary

Ski racers train with a team, however it is an individual sport. While course training, racers usually go up the ski lift by themselves or with another teammate, as they take turns in the course. Racers also interact with their coaches. However, during free-skiing training, the whole team goes up the chairlift at the same time.

Motivation

Ski racers are mainly motivated by having fun. Other motivating factors include the love of competition, the desire to win, and the desire to improve skills.

Figure 3. Data from An Analysis of Alpine Skiing 2016.

Lifestyle

Most racers in this age group are also seriously competitive in another sport and lead very active lifestyles. They are also in school full time.

Focus and Exertion

As ski racing is a physical task, racers need to be physically fit. As racers between the ages of 10 and 14 are going through growth spurts, they are not as strong as they need to be in order to acquire certain skills. Therefore, it may take more effort to achieve goals. While learning skills, racers must have a high level of focus because they must understand what their coaches are teaching them and be able to execute the instructions.

Location

Skiing happens at ski resorts on hills and mountains with snow.

Figure 4. A map of all the ski areas in Canada (Percoski, n.d.).

2.1.3 Activity Mapping

This thesis is focused on developing alpine ski racers between the ages of 10 and 14 by making communication easier. Current on-hill skill development is achieved through verbal

communication, which can be misunderstood. Skiers are also trained with drills, which may be completed incorrectly. Non-active training is carried out through observation, which is done with the racer standing still, and video review, which happens at the end of the day when the racer is off-snow. There is currently no training device that improves a racer's skills while they are skiing.

Athletes must understand what their coaches are trying to tell them in order to succeed. Communication goes beyond verbal exchange. It can include copying physical movements and non-verbal cues. The purpose of this observation is to understand how coaches and racers communicate with each other and attempt to identify barriers and where improvements can be made. This information will be collected through an observational study at a hockey practice.

Method

An observation was completed to identify how coaches and athletes communicate (details found in Appendix ii - User Observation Report). Questions that were asked include:

- What are the main forms of communication?
- How do athletes and coaches react to each form of communication?

User Experience Map

Step number	Photo	Description
1	 *Figure 5.* Hockey team listening to the coach explain a drill.	Coach explains drill verbally at boards
2	 *Figure 6.* Hockey team watching the coach explain a drill.	Coach draws explanation on boards
3	 *Figure 7.* A coach and player demonstrate a drill.	Coach gives physical demonstration with player

4	 *Figure 8*. Two players completing a hockey drill.	Players start drill
5	 *Figure 9*. Coach watching players complete the drill while giving corrections.	Coach yells out key words for reminders
6	 *Figure 10*. A player preparing to shoot at the goalie.	Players get better at drill

Results

The observation reaffirms the information collected in the interviews. Throughout each drill process, the three previously discussed communication methods were all observed. Verbal communication was the most common method, and it was often used in conjunction with visual communication. Kinetic communication was the most interesting to observe because it

provided the clearest explanation for each drill. The information collected in this observation will be useful when designing the solution for this thesis problem.

2.1.4 Ergonomic Research

Figure 11. This image shows the size difference of a 5th percentile 10-year-old male and a 95 percentile 14-year-old female while skiing.

Figure 12. This image shows a 5th percentile female hand and a 95th percentile male hand in relation to the Motorola GP328.

Currently, the only piece of technology used in on-hill training to communicate is a Motorola radio. However, its use is usually restricted to communication between coaches. It is large and heavy, making it unwieldly for a racer to carry while training.

A product that is closer to the thesis solution, in terms of physical feedback, is the CARV Digital Ski Coach. However, this product is not used by amateur ski racers. This product takes up space in ski boots, which changes the fit of the boot, which can impact performance. Many racers also have battery powered heated footbeds to help prevent frostbite. As the batteries are placed on the back of the ski boot, the addition of the CARV battery would require racers to attach two batteries to each ski boot, which would be difficult to fit. Additionally, CARV requires the use of an app, which means every racer must carry a cell phone with Bluetooth, which is not realistic for children between the ages of 10 and 14. Also, to receive feedback, one must take their phone out on the hill, which is difficult to do in ski equipment. The CARV app only provides feedback in one format, while a human coach would be able to explain the same concept in several different ways.

Most of the thesis solution will be built in clothing sizing, as it will need to fit snuggly on growing children's bodies.

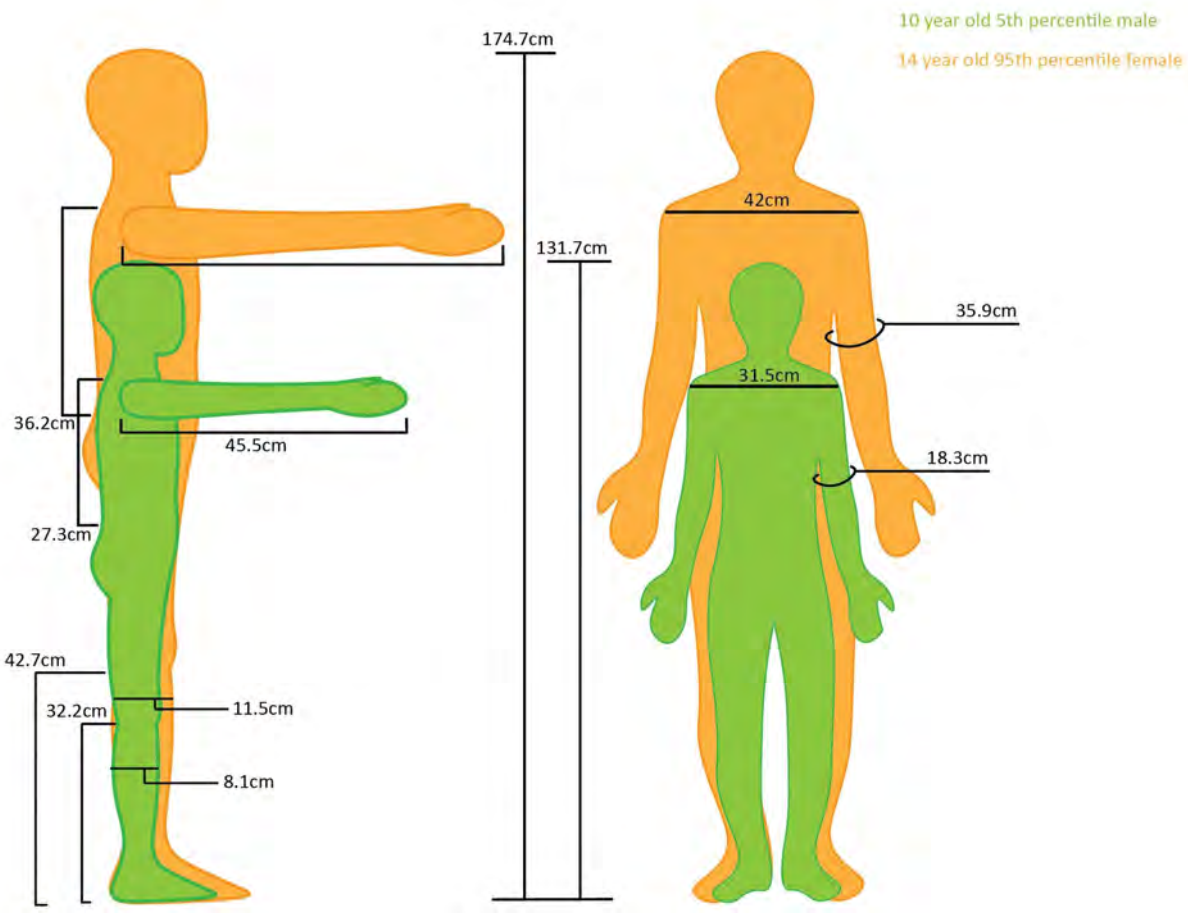


Figure 13. Necessary ergonomic measurements.

All data was collected from *The Measure of Man and* Woman by Henry Dreyfuss, and *Selected Body Measurements of Children 6-11 Years* from the U.S. Department of Health, Education, and Welfare.

2.1.5 Safety and Health Research

The injury rate at youth levels has been reported to be 0.63 traumatic injuries per athlete per season (Müller & Liu, 2018). The most common overuse injuries are back injuries, due to "...the combined occurrence of frontal bending, lateral bending, and torsion in the highly loaded trunk during turning. These movement and loading patterns create high spinal disc loading" (Müller & Liu, 2018). Additionally, the risk of sustaining an overuse injury is heightened during a growth spurt (Steidl-Müller, Hildebrandt, E, Fink, & Raschner, 2018). Growth spurts change body composition and may increase the development of imbalanced limbs, specifically legs (Steidl-Müller, Hildebrandt, E, Fink, & Raschner, 2018). This can make a racer unbalanced, which heightens the risk of injury (Steidl-Müller, Hildebrandt, E, Fink, & Raschner, 2018). Balance is affected by age and maturity (Raschner, Hildebrandt, Mohr, & Müller, 2017). Skiing demands lateral and forward-backward balance over changing terrain (Raschner, Hildebrandt, Mohr, & Müller, 2017).

Additionally, skiers are exposed to low temperatures during training and races. The cold weather affects the nervous system and physical and cognitive performance, which decreases postural control and increases injury risk (Raschner, Hildebrandt, Mohr, & Müller, 2017). Therefore, ski racers must have muscular strength and power, balance, and agility (Raschner, Hildebrandt, Mohr, & Müller, 2017). To prevent injury, racers should be trained in balance and neuromuscular efficiency (Raschner, Hildebrandt, Mohr, & Müller, 2017). Their proprioceptive, visual and vestibular systems must also be trained (Raschner, Hildebrandt, Mohr, & Müller, 2017).

2.1.6 User Interviews

Athletes must understand what their coaches are trying to tell them in order to succeed. Communication can include verbal exchange, copying physical movements, and non-verbal cues. The purpose of this interview was to understand how coaches and racers communicate with each other and attempt to identify barriers and where improvements can be made. This information was collected through interviews with a U14 racer and a coach (see Appendix ii – User Observation Report).

Method

Interviews were completed to identify how coaches and athletes communicate (details found in Appendix ii - User Observation Report). Questions that were asked include:

- What are the main forms of communication?
- How do athletes and coaches react to each form of communication?
- Are there ever issues with communication?

Results

The interviews provided insight into how athletes and coaches perceive communication with each other. The athlete and coach that were interviewed both said that they recognize that people have different learning styles. Both discussed visual, auditory, and kinetic learning styles. The racer said that he is a visual learner and prefers to see demonstrations. The coach also said, "…if I show them, they get it." Auditory learners understand verbal instructions best. However, the racer said that sometimes he does not understand what a coach is saying and asks for further explanation. Sometimes this is not enough, and he needs a visual demonstration. The coach recognizes that it is her responsibility to communicate clearly and

help the racer understand what she is saying. She said that she often asks racers to explain concepts back to her so she knows that they understand. If they cannot do it, she re-explains the action a different way or shows them. She finds that for some children kinetic learning is most effective. She has the racer stand sideways on the hill and physically puts their body into the position she wants them to achieve while in motion so they can feel it. These three methods of communication can inform the product's design.

2.2 Product Research

2.2.1 Benchmarking – Benefits and Features

This thesis focuses on bettering communication between racers and coaches while training. In order to design a solution for the posed thesis problem, current communication and coaching products have been benchmarked. As there are few products currently used to communicate between ski racers and coaches, products used in other sports were also collected. The products being compared are:

- Motorola GP328 (A)
- Bonx (B)
- Digital Long Track Mobile System – CM300D (C)
- Sena Expand (D)
- Rossignol & PIQ Wearable Ski Sport Tracker (E)
- Carv Digital Ski Coach (F)

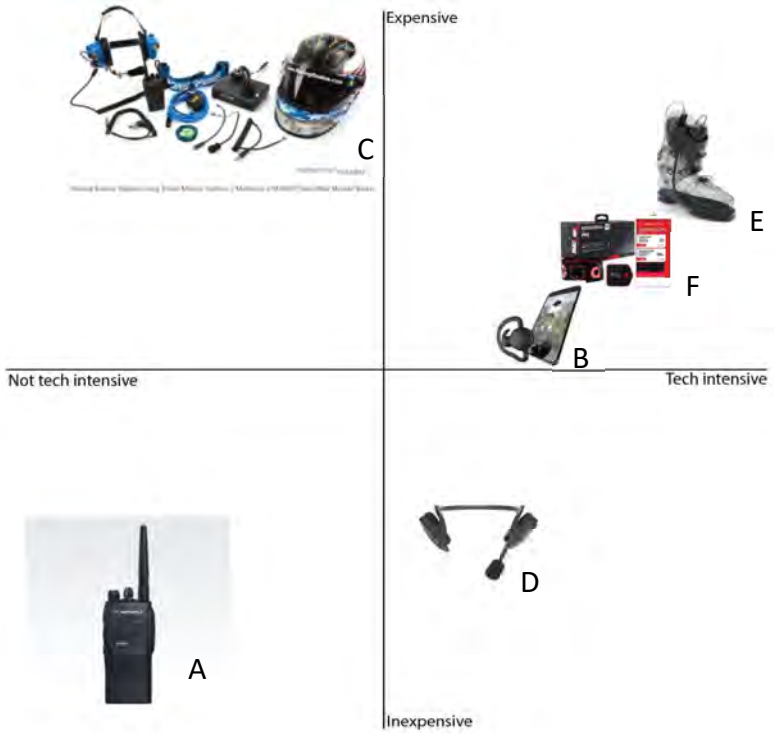


Figure 14. A product map comparing how technologically intensive the benchmarked products are versus the price.

Figure 15. A product map comparing the battery life and how heavy/big the benchmarked products are.

When comparing all four features, it can be seen that the ideal product in this market is the Sena Expand. This product is small, has a good battery life, is not too expensive, and not too technologically intensive. These scatter plots reveal design opportunities. The products shown are either verbal communication aids or training aids. There are opportunities to combine the communication aspect with the sensory responses in the training aids.

Features and Benefits

A wide range of products were investigated (see Appendix iii – Product Research and Benchmarking) which determined the features and benefits that were common between some of them. The following table will briefly identify these characteristics

Features	**Benefits**
Batter powered	Lightweight
Waterproof	Communication
Voice activated	Waterproof
	Voice activated

2.2.2 Benchmarking – Functionality

The functionality of each product varies depending on the context in which it is used. Some of the products are radios, some use Bluetooth, and some are sensor-based training devices. Each product has a varying degree of accessibility and complexity. However, all of the products are used for communication or communicate with the user in some way.

The most commonly used communication product in alpine ski racing is the Motorola GP328 because it is durable, has a long-lasting battery, and is not too expensive. However, it is

heavy. The product that is most functional is the Sena Expand headset as it is lightweight, has a long-lasting battery, and is not too expensive. These examples help inform the necessary functions for the design solution.

Necessary Functions:

- Communicate with the primary and secondary users.
- Aid communication between the primary and secondary user.
- Long battery life.
- Not technologically intense.
- Lightweight.
- Durable.

2.2.3 Benchmarking – Aesthetics and Semantic Profile

The benchmarked research on existing communication products for skiing and other extreme sports aid in the styling and design development of the product solution. As the designers of these benchmarked products want to create something that is durable, they do not worry about making the product look pretty. More often than not form follows function. The products that are more often used in a serious competitive environment look durable and intense, while the products that are for less serious athletes or for pleasure look sleek and modern. However, none of the products have additional features unless they are necessary. Additionally, all of the benchmarked products are black, and the materials used are for durability rather than comfort. Also, the shape of the products differ because they have different functions. This can be seen in the products presented in section 2.2.1.

2.2.4 Benchmarking – Material and Manufacturing

Current products often use rigid plastic, such as the Motorola GP328 and the CM300D of the Digital Long Track Mobile System. The cases of these devices appear to be injection molded. Bonx is made of a soft rubber so that it is comfortable to wear throughout the day. While there is no information on the Rossignol & PIQ Wearable Ski Sport Tracker, Sena Expand, or Carv Digital Ski Coach, it can be assumed that these devices are all made of plastics and fabrics.

2.2.5 Benchmarking – Sustainability

Sustainability is an important factor to consider when designing a new product. Looking at the benchmarked products' companies' sustainability initiatives assisted in this process.

Motorola considers their products' entire lifecycle. Some examples of their initiatives include using recycled plastic where possible, and their chargers use less energy than U.S Environmental Protection Agencies ENERGY STAR standard (Motorola Mobility LLC, n.d.). They also give information to their customers on how to dispose of their products properly (Motorola Mobility LLC, n.d.).

Rossignol joined Global Compact in 2015 (Groupe Rossignol, 2019). The company only uses synthetic fur, 64% of the down they use is synthetic, and the rest of the down, feathers, and leather are food-industry by-products (Groupe Rossignol, 2019). Several clothing items they produce use polyester made from recycled materials, and their ski helmets are now 100% recyclable (Groupe Rossignol, 2019). Additionally, Rossignol will collect equipment at the end of its life to dispose of each part properly (this includes skis, snowboards, poles, and ski boots)

(Groupe Rossignol, 2019). Only a few initiatives have been mentioned as this company creates a wide range of products.

3 Analysis

This chapter analyzes the product and user research findings from the previous chapter, investigates the user experience, and evaluates whether or not their needs are being met by current products and practices. These needs are categorized, and the users' latent needs are investigated.

3.1 User Needs Analysis

Good communication is vital if a ski racer is to develop, improve and succeed. As seen in the research in the previous chapter, communication happens verbally, visually, and kinetically. Primary and secondary users will benefit from a product that lowers communication barriers by using all three forms of communication. This product solution will therefore enhance communication and help racers improve.

3.1.1 Needs/Benefits not met by current products

The existing communication products listed in section 2.2.1 all have slightly different functions. None of the products meet all of the users' needs on their own. As seen in the user interviews and observation (see Appendix ii – User Observation Report), users learn best when verbal, visual, and kinetic types of communication are used in tandem.

Needs	**Benefits**
Comfort/ease of use	- Functions of product do not inhibit movement - Ergonomic for both primary and secondary users - Clear on how the product is used
Efficiency	- Provides feedback for many skills in many ways - Helps racers retain skills quicker

Aesthetics/styling	- Visually attracts racer to want to use the product
Rigidity	- Some parts of the product must be made of rigid material to withstand the environment in which it is used

3.1.2 Latent needs

Latent needs are needs that the users may not realize they require, or subconsciously require.

Enjoyability

While training for an elite sport can be serious, it is important that the racers are still enjoying themselves. One of the top reasons racers continue in ski racing is because they have fun while training and racing.

Esteem

An overlooked area of skills training is nurturing the self-esteem in young athletes. When learning a specific skill, racers can become frustrated because they are not picking it up as quickly as they would like to, or they may not understand what their coach is trying to teach them. It is important to find a way to help the racer understand better so they can learn and gain confidence in their skills.

Safety

While safety is not overlooked in ski racing, it can be when using objects during skills training. Designing a product that is safe to use during on hill training is vital.

Rigidity

The product must have some toughness as it will be worn and used while training in cold temperatures. It is also able to withstand impact, as racers often hit gates and can fall hard. The product must also withstand the vibrations that come through the body from the uneven ever-changing snow the racers train on.

3.1.3 Categorization of needs

This thesis project focuses on improving communication between ski coaches and racers. The areas of focus include ease of use for all users, comfort for all users, and including more than one communication style in the solution. These needs were identified via research, interviews, and observations, as well as my personal experience.

Wants

- Products that communicate in more than one communication style
- Easy to use
- Adaptable
- Enhances training experience

Immediate needs

- High adjustability
- Comfort and ease of use for both users
- Efficient

Latent needs

- Easy to replace or fix

- Rigidity
- Enjoyable to use and enhance the training experience
- Boost self-esteem by making communication better

3.1.4 Needs Analysis Diagram

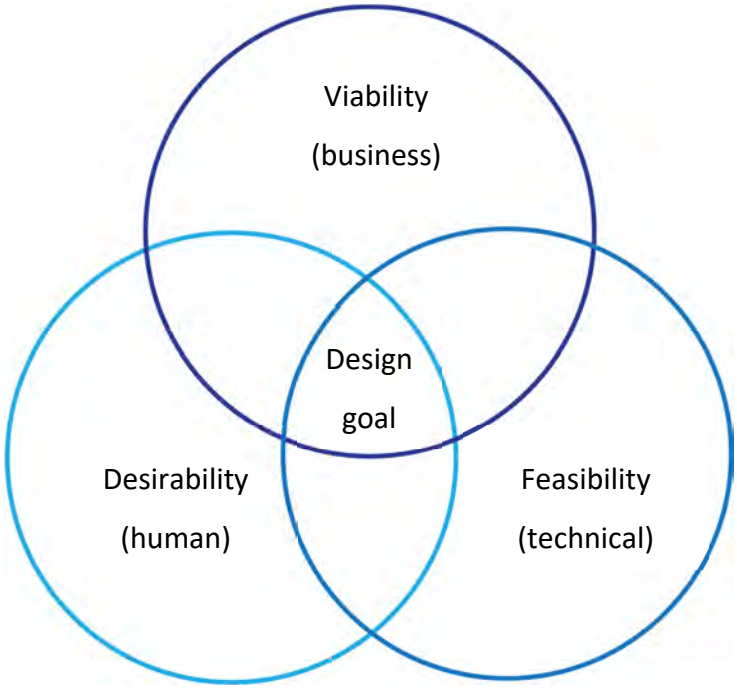


Figure 16. This chart represents where to find successful human-centered design.

A successful human centered design covers three categories: feasibility, desirability, and viability.

Feasibility

The solution incorporates the three communication styles mentioned earlier. The technology exists to be able to create a revolutionary product solution.

Desirability

The users must want to use the product solution. It must aid in the communication between coaches and athletes and ease the training process.

Viability

The solution should be available for all users and should help keep racers in the sport for longer.

3.2 Functionality

3.2.1 Activity/Workflow Mapping

In section 2.1.3 a hockey practice was observed, and key activities were mapped and analyzed.

Key Activity One

Verbal instruction was the most prominent communication method. The coaches would verbally explain the drill while drawing on the board. The coach would also explain while demonstrating each drill, and while the team was completing the drill.

Key Activity Two

Visual communication was used during verbal communication. One of the coaches would draw each drill on the board while explaining it verbally. Then he would physically demonstrate the drill while verbalizing the steps so the team could see what he was explaining in real time. The team also learned through visual communication by watching their peers.

Key Activity Three

Kinetic communication was mostly seen through the repetition of drills. It was also achieved by the coaches physically demonstrating the drill before the players completed the

drill. There was, however, one big kinetic communication session when the coach and the goalie were working together one-on-one when the coach broke down each step of the goalie's exercise slowly. Very small movements were repeated slowly before putting them together into one motion.

3.2.2 Activity Experience Mapping

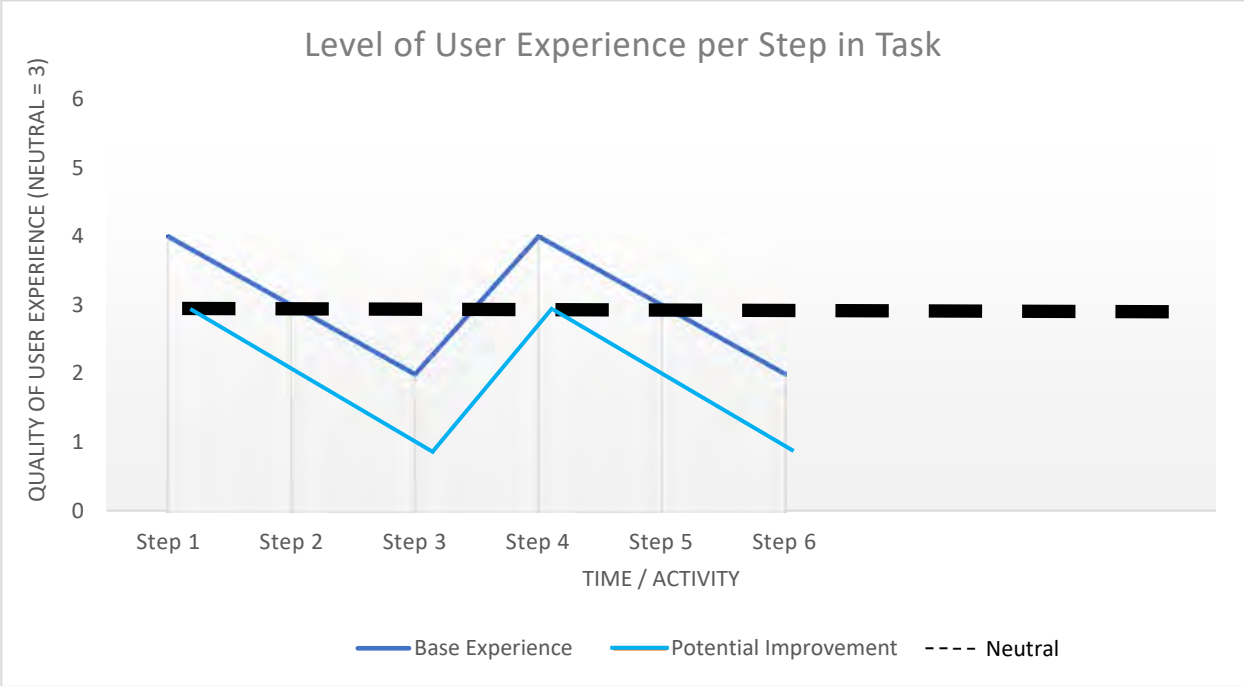


Figure 17. Current understanding difficulty vs. target understanding difficulty.

This observation shows that the players' understanding improves as each drill progresses. When the coach is verbally explaining and drawing on the board there is some understanding, however there is still some difficulty. As the drill progresses, the understanding improves. As the players are still learning, their understanding can never be at 'level 1'. Ideally, the players' first level of understanding should be neutral, and improve from there.

The steps have been altered from a hockey practice drill to a ski racing on-snow drill. The steps are similar, simply the wording has been changed to relate more to the thesis topic.

Step	Current Steps	Potential Improvements
1	Coach A explains drill verbally on hill.	Coach A explains drill verbally on hill. This first step is the same as it is the best way to start.
2	Coach B gives physical demonstration (or has a reliable racer demonstrate). Coach B stops in the middle of the hill to watch each racer perform drill.	Coach A and B give physical demonstration of drill. This allows racers to visualize what their bodies are supposed to look like. Both coaches stop at bottom of hill to watch each racer perform drill.
3	Racers go down the hill one by one doing drill (spaced out by coach A).	Racers go down hill two at a time (if there is no space one at a time). Racers are spaced out by coaches sending visual or radio signal.
4	Racers stop at coach B, receives verbal feedback. Simultaneously coach A points out corrections or good movements to the racers standing at the top of the hill to give a visual for them to learn from.	As each racer is skiing, coach A or B is able to give feedback while racer is in motion. This allows the racer to make immediate corrections to their movements.
5	Racer continues down the hill trying to implement corrections coach B just gave.	Racers can continue to rotate, not having to stop at the coaches for feedback,

		which will allow racers to get more runs in and more time on snow.
6	Racers' skills improve through repetition.	Racers' skills improve through repetition and visual, verbal, and kinetic reminders from coaches.

3.3 Usability (Ergonomics report)

Introduction

Key areas that the design solution interacts with are the head, arms, lower back, and calves. It interacts with the head through sound, covering the verbal/auditory communication aspect. The other parts of the body, arms, lower back, and calves are important focus points for young ski racers. These parts of the body are interacted with through vibrating sensors, covering the kinetic aspect of learning. The solution interacts with the arms because young racers need to work on keeping their arms up in front of them and pole planting. The lower back interaction helps racers with vertical movement and will give them a reminder to 'dive' down the hill. The calf interaction reminds racers to keep pressure on the front of their boots and therefore help with forward-backward movement.

Literature Review

The anthropomorphic data that has been referenced is from *The Measure of Man and* Woman by Henry Dreyfuss, and *Selected Body Measurements of Children 6-11 Years* from the U.S. Department of Health, Education, and Welfare. The dimensions of the 5th percentile 10 year old male and the 95th percentile 14 year old female have been referenced, along with a 5th percentile adult female and a 95th percentile adult male.

Methodology

Two parts of the solution have been created and tested. This includes an ergonomic buck for calf sleeves and the coach's arm band. The upper-body ergonomic buck was not built because it has to be made in individual clothing sizes and would not be able to fit both the 5th percentile 10 year old male and the 95th percentile 14 year old female. It also fits like a long underwear shirt.

Objectives

The aim was to find the ideal size of a calf sleeve and helmet ear piece that can fit on the majority of children between the ages of 10 and 14 and in their helmets. The sizing of the participants long underwear shirts was also recorded as the main body of the thesis solution will follow standard clothing sizes. The major body parts being considered are the lower legs, upper arms, shoulders, lower back, and ears.

Evaluation process

The evaluation process of this ergonomics study consisted of using existing calf compression sleeves and observing how they fit on a 5th percentile 10 year old male and a 95th percentile 14 year old female. Additionally, a cardboard ring was used to evaluate the sizing of

the helmet ear piece that would be able to universally fit into a hard-eared regulation helmet. These bucks allow for the observation of the following:

1) Can calf sleeves come in only one size or should there be a small-medium-large system?
2) Are the ear-pieces comfortable on the inside of the helmet, or should they be places on the outside?
3) Are calf-sleeves comfortable to wear over socks and long underwear or should the technology be integrated into socks or something that attaches to the calf of the ski boot?

Description of users targeted by product

The primary target demographic is ski racers between the ages of 10 and 14. However, the product's usability must also be targeted to ski coaches, who are over the age of 16.

User Observation Environment Used in This Study

While these products in practice will be used while skiing, photos of them must be taken while the user is undressed of external gear and not moving. Therefore the observation took place inside before the training day started.

Location and Timeframe

Location of observation: Alpine Ski Club.

Date of observation: December 31, 2019.

Results

The results were illustrated and/or photographed. The ergonomic drawings are constructed using relevant data for the 5th percentile 10 year old boy and the 95th percentile 14

year old female. The physical buck that was used was used for its universal sizing, to determine of other sizes are necessary.

Ergonomic Drawings

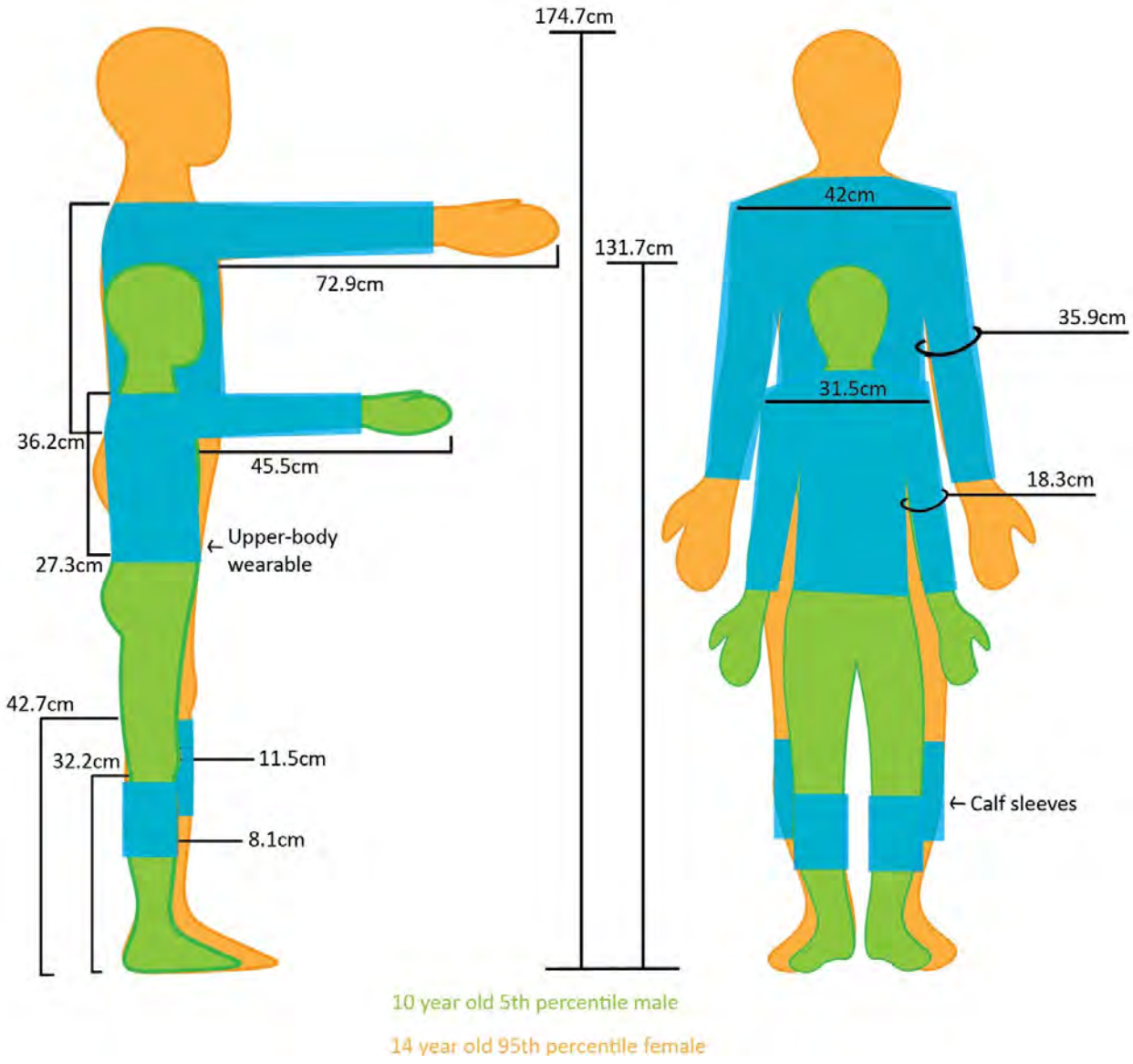


Figure 18. Users and anthropomorphic measurements with design solution for reference.

The major physical interactions with the product are illustrated above. The calf sleeves are made of stretchy material, and therefore one size fits most. It sits comfortabley under the

knee and above the top of the ski boot. This is so there is not discomfort in the ski boot due to the extra material. However, the shirt must be made in regular clothing sizes, and it must be close the skin, but not restrict any movements.

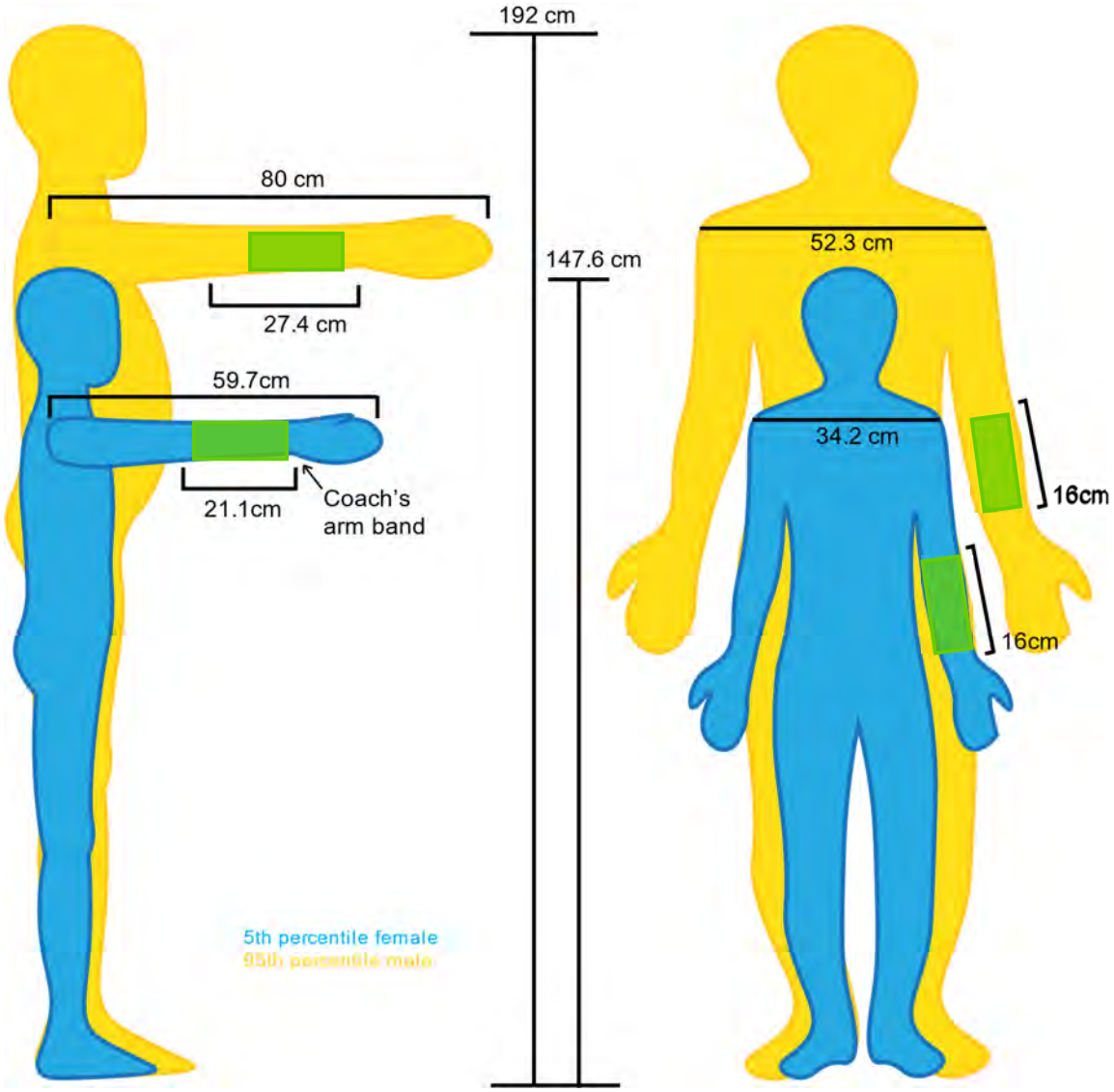


Figure 19. Users and anthropomorphic measurements with design solution for reference.

The major physical interaction for the coach interaction is illustrated above. The arm band is curved and made of a hard plastic. It is adjutsable to the arm through velcro bands. It

sits on the forarm of the coach, and the coach uses it to interact with the vibrating sensors and ear piece of the athlete.

Ergonomic Buck User Observation

For this observation, photos of a 10 year old male who is 131.7cm and and 14 year old female who is 174.7cm were taken. Both tried on and interacted with the ergonomic buck. Notes were taken on their opinions throughtout each interaction.

For the coaching armband observation, a 5th percentile female and a 95th percentile male was used.

Athlete Wearable

The ergonomic buck used is made from compression calf sleeves cut so they are 12cm long and 5cm wide when flatted.

Figure 20. 14-year-old girl, 5'8" wearing calf sleeve.

This photograph shows the calf sleeve sitting comfortably below the knees. While it does fit, the wearer mentioned that it is slightly too tight, and could become uncomfortable during sustained wear-times. Additionally, the size of the shirt the user is wearing is adult medium. The location of the vibrating sensors have been marked in yellow on the long underwear shirt. The pink strip is the where the protective backboard will sit.

Figure 21. 10-year-old boy, ~4'3".

This photograph shows the 10 year old male. It was much easier for him to put the compression calf sleeve on. It was much looser on him than on the 14-year-old female, and would likely cause no discomfort while skiing.

The pocket that holds the battery on the compression sleeve sits on the outside of the calf. Both users said that it was easy to access and in a safe place that would not interfere with skiing.

Coach Wearable

Figure 22. Users wearing ergonomic buck of coaching arm band.

This arm band interacts with the athlete's wearable and the helmet ear piece through radio signals. The band straps onto the outside of a jacket, using Velcro to adjust the tightness around the forearm. The arm band is 16cm long and 12cm wide.

Figure 23. Users pressing the PPT button.

Both users said that the arm band was more convenient for using the radio than the current solution (the Motorola GP328). The users like that they do not have to take it out of their pocket every time they want to communicate verbally. The arm band also allows the coaches to communicate while skiing, instead of having to stand still to use the radio like they currently do.

Figure 24. Users pressing the buttons that correspond to athletes' wearable.

Both users thought that the buttons corresponding to the athletes vibrating sensors were in convenient places, as they would just have to naturally bend their arm to access them.

Figure 25. Users changing the radio frequency to communicate with different athletes.

Both users are able to move the channel dial with gloves on.

Analysis

The proposed design solution will make ski race training better through the improvement of communication between coaches and racers. Through this ergonomic study, it can be seen that there are many elements of the proposed design solution that can be put into use. The interaction showcased above is similar to the interaction that will take place on the ski hill. However, certain inconsistencies, such as weather and the communication system not connecting properly, cannot be tested. Additionally, coaches and athletes were asked about the wearables and where adjustments and improvements can be made.

In order for this system to work, the racers' wearables must be relatively tight to the body. This is so the racers will be able to feel the vibrations when the coach sends the signal, and therefore correct their positioning. This will also stop the wearables from shifting too far on the body, which would put the vibrations out of place. The athletes mentioned that the batteries should be removable for charging. They also said that the vibrating sensors should be as flat as possible so as to not interfere with the other equipment that they are required to wear on their upper bodies (such as stealths and backboards).

When wearing the calf compression sleeve model, the 14-year-old said that it could become uncomfortable over a days-worth of skiing due to how tight it is. She also mentioned that, due to the tightness, it may cut off some circulation, which will cause the racer to lose some feeling in their feet or make their feet feel cold faster. This is not good because a racer must be able to feel their feet in order to exert pressure on their skis through their boots. It was suggested that the calf sleeve be adjustable through Velcro straps, or to make it a piece that slides into the back of the ski boot. This feedback was very important to the continuation of the design process.

The coaching arm band sits on the forearm of the coach. It has a gear shift style dial to change radio frequencies to make it possible to interact with different racers. There are buttons that the coach presses to set off a vibrating sensor on an athlete's body, and a speaker to verbally communicate with each racer. This observation shows that the arm band fits comfortably over the jacket of a 5th percentile female and a 95th percentile male. It is adjustable with Velcro straps.

The users said that the placement of the speaker and push-to-talk button were convenient, as all they would need to do is bring their hand to their mouth, which is a simple motion. The users like the idea of having the gear shift style frequency control because it ensures that the frequency will not change while they are communicating with an athlete. The users would like to see the buttons organized differently and for them to be larger. They expressed concern that when they are trying to react quickly to how a racer is skiing, they may press the wrong one as their mittens or gloves are large and can accidentally press multiple buttons at once or block the one that they intend to press. There are many possible solutions to this issue including larger buttons, a different configuration of the buttons, or a different physical design of the armband. All of the buttons on the arm band must be tactile and give the coach obvious physical and/or audible feedback. This is because the coach will be wearing gloves or mittens, which dampens the sense of touch.

3.4 Aesthetics

Currently, coaches and racers most often communicate verbally when on the ski hill. Visual communication is achieved through watching others complete a drill, and kinetic

communication is achieved through repetition. There are currently no products designed to teach a racer while they are in motion.

The more popular benchmarked products' form follows its function. Aesthetics and styling are low on the list of priorities, as users care more about what the product does than how it looks or feels. However, styling is considered for three of the benchmarked products: the Rossignol & PIQ Wearable Ski Sport Tracker, Bonx, and Carv Digital Ski Coach. These products are not used for the development of young athletes, but rather for an adult skier's personal improvement or to stay in contact with friends while skiing. However, the aesthetics and styling from these products help to inform the thesis design solution.

Brand recognition is also important. For example, Motorola has reliable products and is therefore the most highly used brand for communication in extreme sports and extreme temperatures. The Digital Long Track Mobile System's radio is also a Motorola product. Another example of a trusted brand is Rossignol. They are one of the most well known and influential brands in winter wear and equipment.

Form Development of Design Solution

The design solution is a wearable that can communicate with the racer in the three communication styles mentioned earlier. Therefore, it interacts with majority of the body. Below, an inspiration board of products for design inspiration was created for reference.

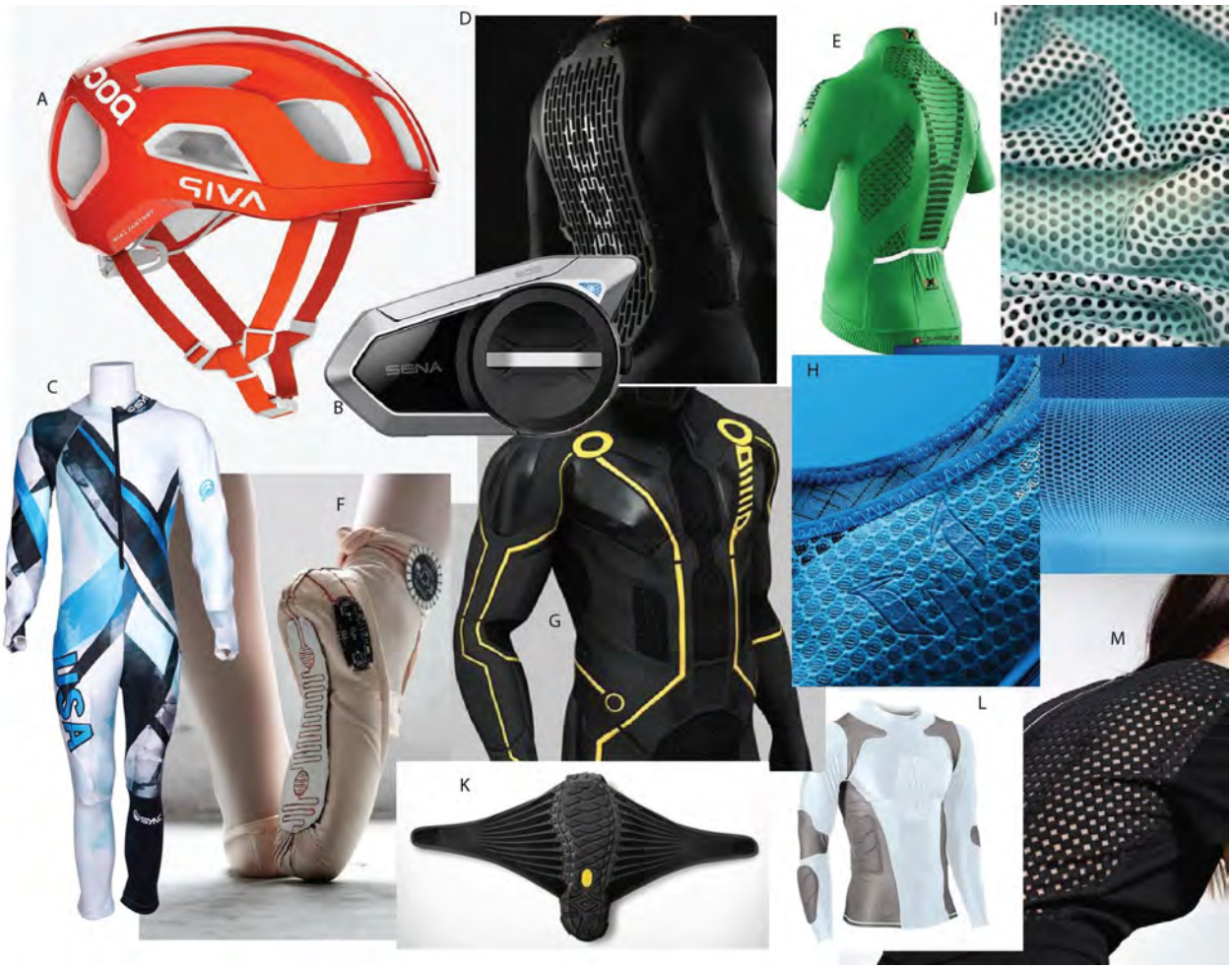


Figure 26. Design inspiration board for thesis solution reference.

A. Helmet, https://www.pocsports.com/us/products/ventral-air-spin/10671.html?dwvar_10671_color=Zink%20Orange%20AVIP&cgid=road-helmets#start=1
B. Bluetooth Ear Piece, https://www.sena.com/motorcycles-powersports/communication#50-series
C. Downhill Suit, https://www.google.com/search?rlz=1C1CHBF_enCA846CA847&biw=1500&bih=841&tbm=isch&sxsrf=ACYBGNSyl0Hyzdw052Q4uMdEpsNiqRnorQ%3A1578535129293&sa=1&ei=2YgWXuW8EYTRtAae6ryYAw&q=kids+downhill+suits&oq=kids+downhill+suits&gs_l=img.3...11196.11601..11823...0.0..0.109.566.6j1.....0....1..gws-wiz-img.....35i39j0i8i30j0i24.3PnjTOV3P18&ved=0ahUKEwiljZbNtfXmAhWEKM0KHR41DzMQ4dUDCAc&uact=5#imgrc=AQay07CNI5UhzM:
D. Back Protector, https://www.pinterest.ca/pin/233202086942595848/
E. Bike Shirt, https://www.pinterest.ca/pin/665547651162317109/
F. Pointe Shoe, https://www.pinterest.ca/pin/37295503143151433/
G. Tron Shirt, https://www.pinterest.ca/pin/759771399612915690/
H. Fabric & Stitching, https://www.pinterest.ca/pin/355643701807808992/
I. Large Mesh, https://www.pinterest.ca/pin/624452304552419862/
J. Small Mesh, https://www.pinterest.ca/pin/531776668482389935/
K. Wrap Shoe, https://www.pinterest.ca/pin/626915210610630231/
L. Padded Shirt, https://www.pinterest.ca/pin/275212227209130797/
M. Mesh Shirt, https://www.pinterest.cas/pin/32088216080972603/

3.5 Sustainability – Safety, Health & Environment

In the area of sportswear, or products used by athletes, the choice of material that is used is important. Anything a racer puts on their body must not hinder any movement for

safety. It also must not cause injury, should the athlete fall, or distract the athlete from their training. Another aspect the product solution must consider is durability and the wear and tear the racers will put on the product. Ski racers fall, hit gates at high speeds, and absorb vibrations from the terrain, so the product solution must be able to withstand these conditions. The product solution will be made, in production, of different types of rigid plastics and breathable fabrics. The material and manufacturing options will follow the patterns of current ski protective wear.

Safety and Health

The most important aspect considered when designing the product solution was the safety of the athlete. Young racers are more likely to sustain an overuse injury due to growth spurts (Steidl-Müller, Hildebrandt, E, Fink, & Raschner, 2018). The primary user group, racers age 10 to 14, are in the middle of puberty and therefore their bodies are constantly changing. It is important to recognize this and design a solution that helps them continue to develop their skills during this time of their lives. When racers understand how to properly move their bodies, good habits are created, and therefore they will be able to continue their development seamlessly during and after puberty. Knowing the proper movements will also likely lower injury rates, as other parts of the body will not be compensating.

The environment must also be taken into account when considering the health and safety of these athletes. As training and racing takes place in cold temperatures, skiers wear many layers. Cold weather affects the nervous system and physical and cognitive performance, which decreases postural control and increases injury risk (Raschner, Hildebrandt, Mohr, & Müller, 2017). The product solution will add a garment layer in some areas, therefore helping to keep parts of the body warm.

Environment

Most often, ski gear and equipment is donated, passed down, or sold when a racer is done with it. As gear is expensive, it is very common for a younger racer to use an older racer's old equipment. Many ski equipment stores will take used equipment and donate them to underprivileged places or send them off to be recycled and disposed of properly.

The product solution uses sustainable materials where possible. This is achieved by using recycled materials, such as plastics and textiles, for the main body of the product. As there are batteries and other technological elements involved, it is important to consider the end of the products life as well. It is important to dispose of all of the parts properly as to not cause more environmental damage.

3.6 Commercial Viability

3.6.1 Materials and Manufacturing Selection

This product is designed to be mass produced. It must be easily accessible to those who need it and maintain commercial viability. Some pieces will be injection molded while other must be fabricated. Due to the necessity for technology, specialized manufacturing will be necessary. There will be little room for customization apart from colourways. The product solution will be easy to use and maintain in order to preserve the longevity of the product.

3.6.2 Cost

The price range for this product should be similar to the products they are similar to. However, the pieces will not be sold as one unit. The racers' upper body wearable, calf sleeves, and ear piece will be sold together, with the option to purchase an upper body wearable

separately when the racer grows. The racers' wearables will likely be purchased by their parents, so the cost must be reasonable. The coach arm band will be sold on its own, and would likely be purchased by a ski resort's race program, rather than the coach.

3.7 Design Brief

The goal of this design thesis is to develop young ski racers. Currently, skills development is achieved through verbal explanation, visual examples, and drill repetition. Additionally, racers only receive feedback on their performance when standing still. This thesis looks to design a solution that allows athletes to get coaching feedback while in motion. The following list guided the design solution.

- Lessen communication barriers between coaches and racers
- Give coaches more resources to reinforce taught skills
- Use the three communication styles: verbal, visual, and kinetic
- Helps make racers more aware of body and muscle control
- Easy to use
- Not disruptive to current training practices
- Sustainable use of recycled materials
- Ergonomic for the primary and secondary users
- Athletic wear design language
- Safe to use

4 Design Development

This chapter focuses on how the design for this thesis was developed from the initial ideation stages through concept and detail development, to the final model. A variety of mediums are used to demonstrate the design process.

4.1 Ideation

4.1.1 Mind Map

The design process began with a mind map that was used to investigate and organize the main issues with communication between racers and coaches. It also investigated user needs and wants, ergonomic requirements, aesthetic look, and the interaction and safety of the product.

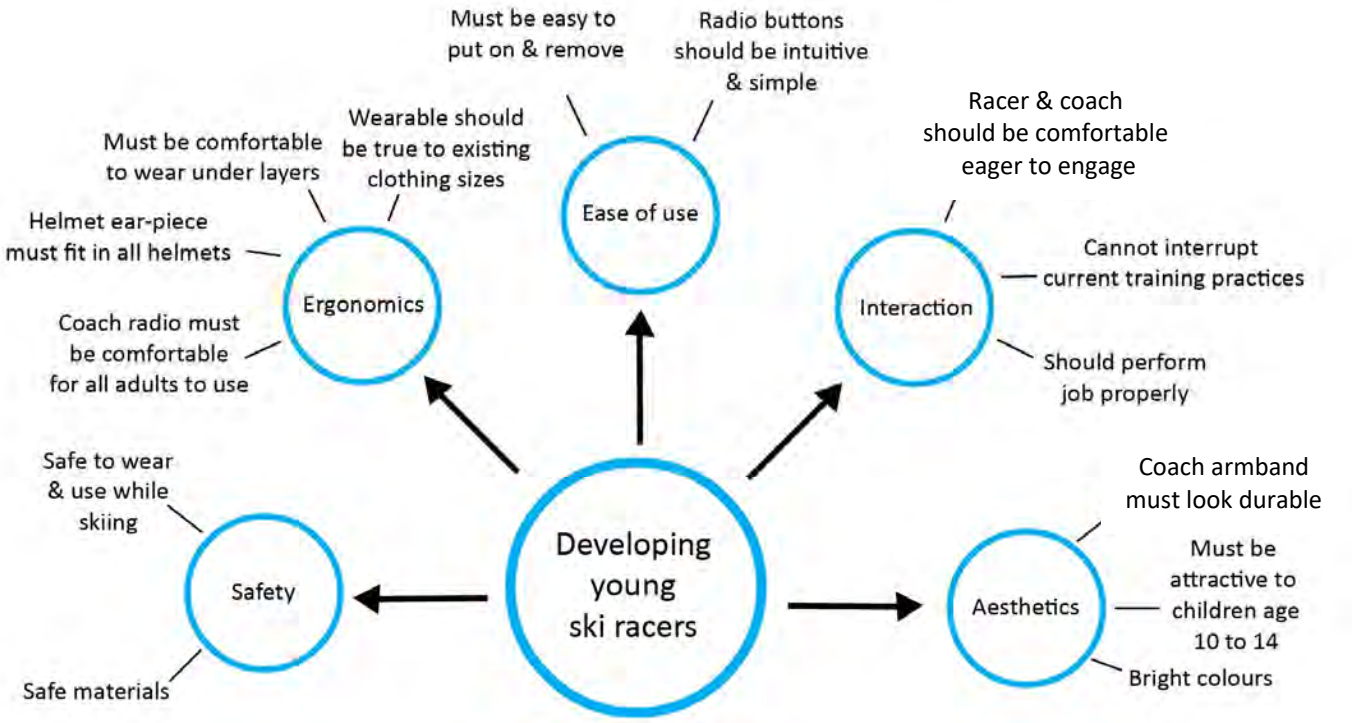


Figure 27. This mind map was made to explore key notes for the major branches.

4.1.2 Inspiration Board

An inspiration board was created using Pinterest and Google searches. These images helped guide the aesthetics, branding, and ergonomics for the design solution.

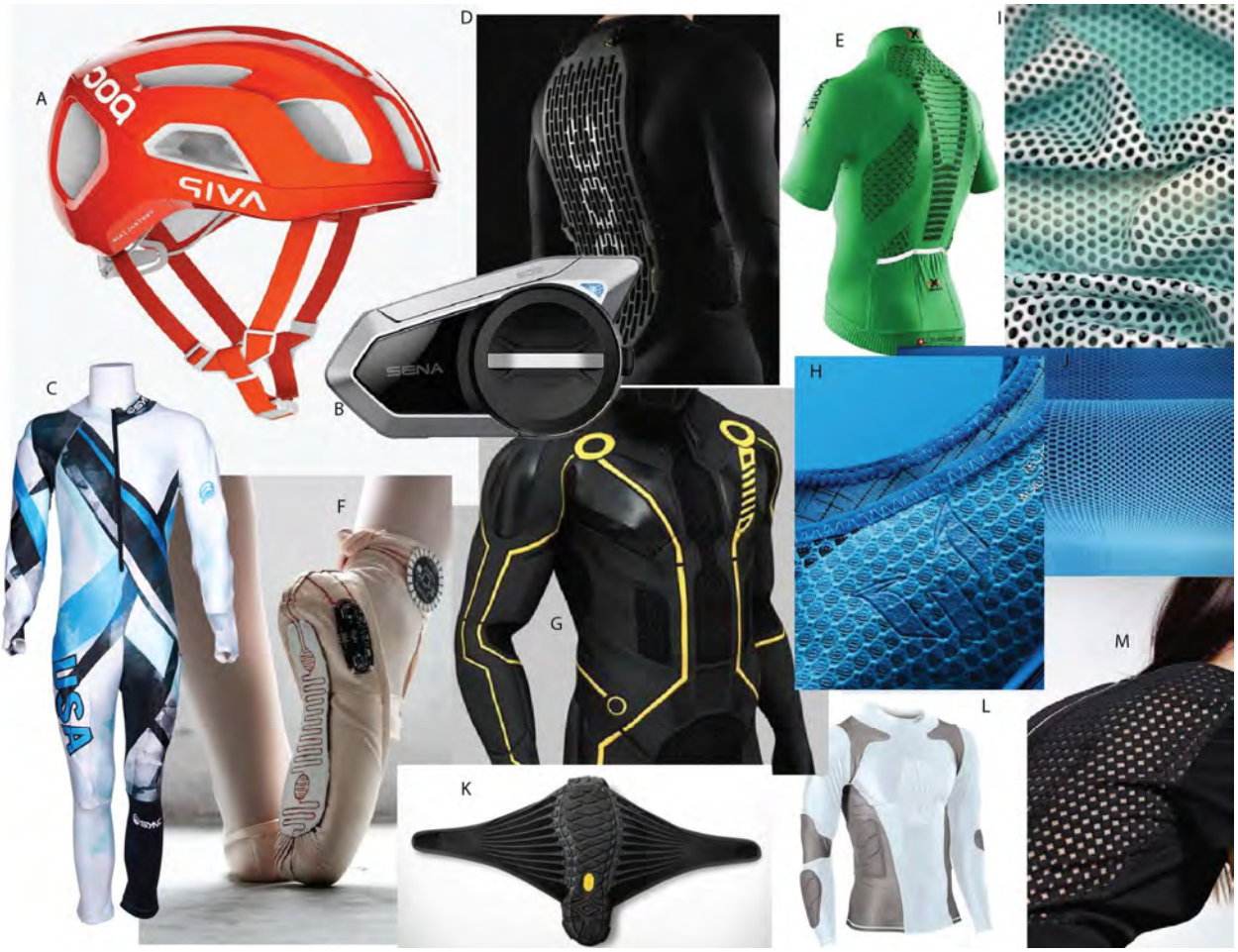
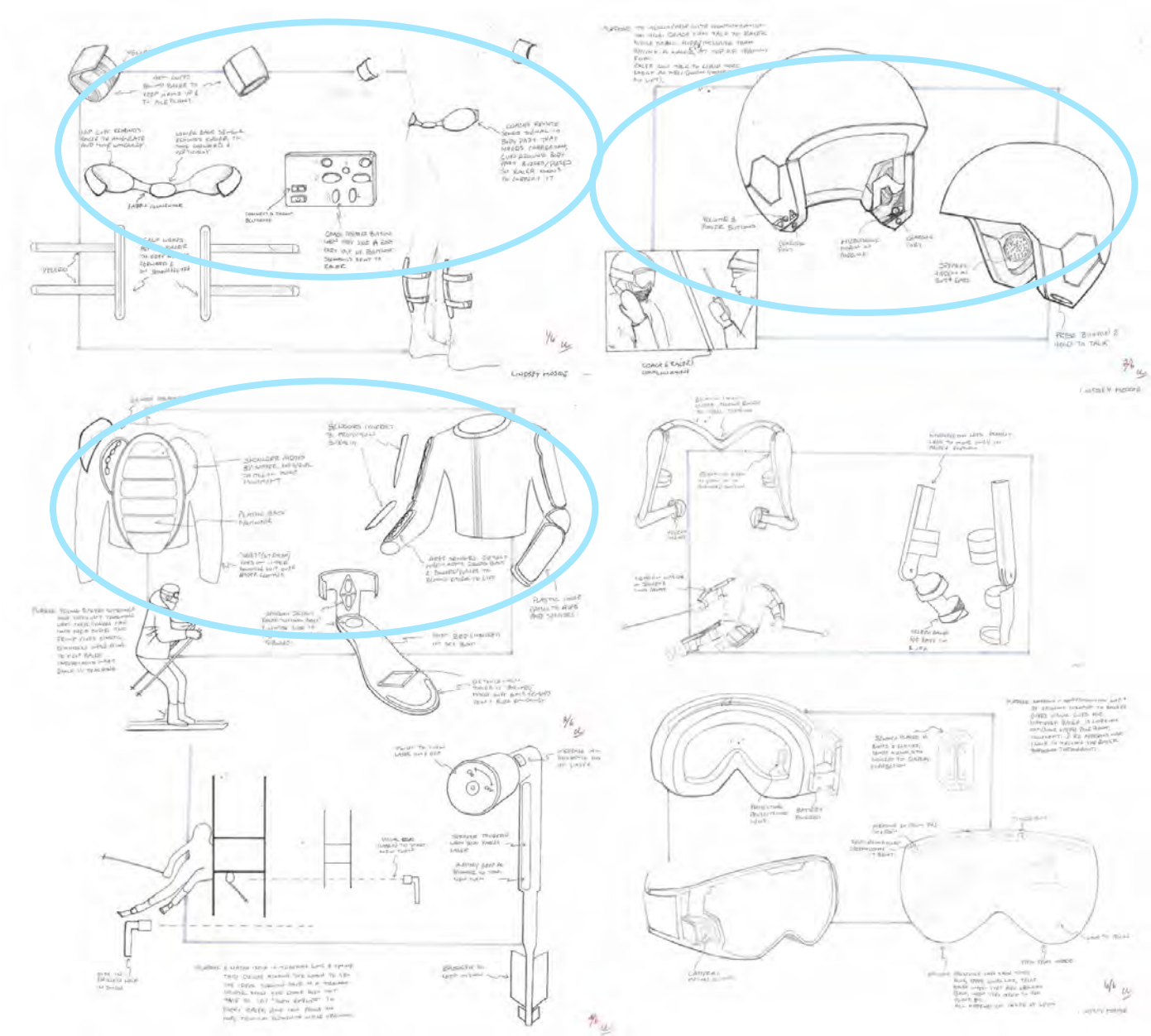


Figure 28. Inspiration board from section 3.4.

4.2 Preliminary Concept Exploration

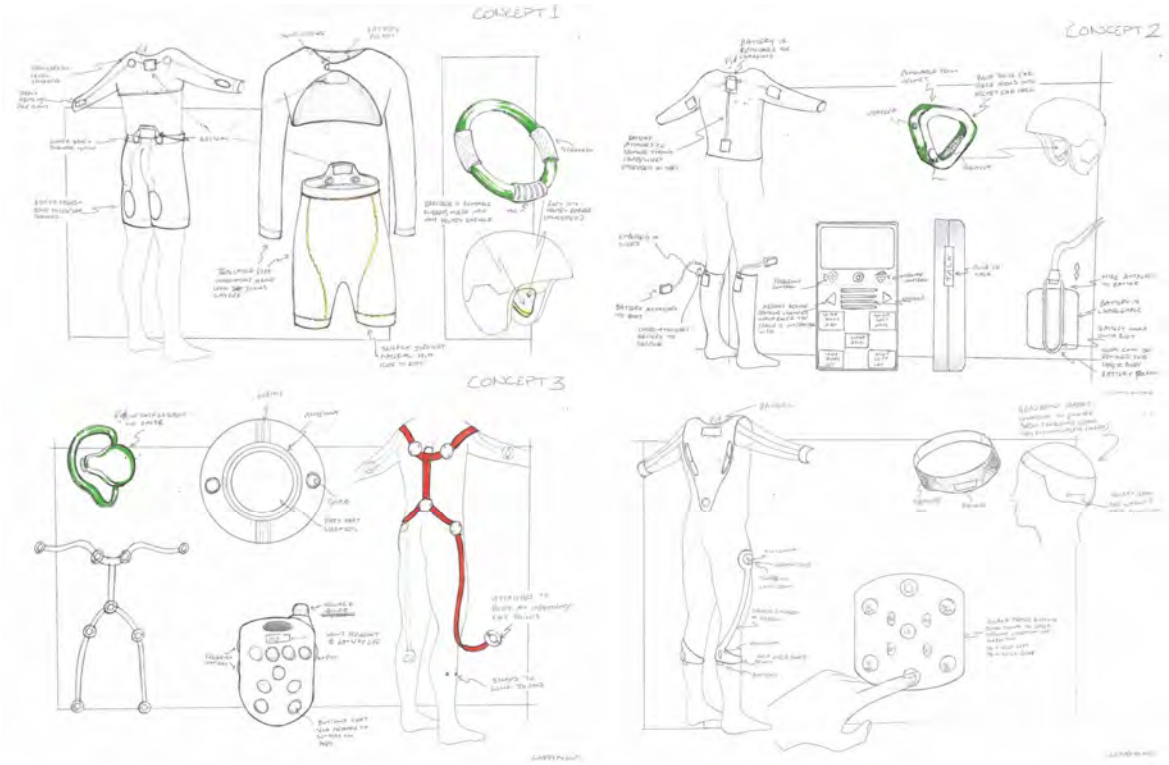
The early concepts sought to investigate as many design paths as possible. They consisted of a variety of products that could aid in the training process by narrowing communication barriers between coaches and athletes. These ideas ranged from goggles and radios to full body wearables.

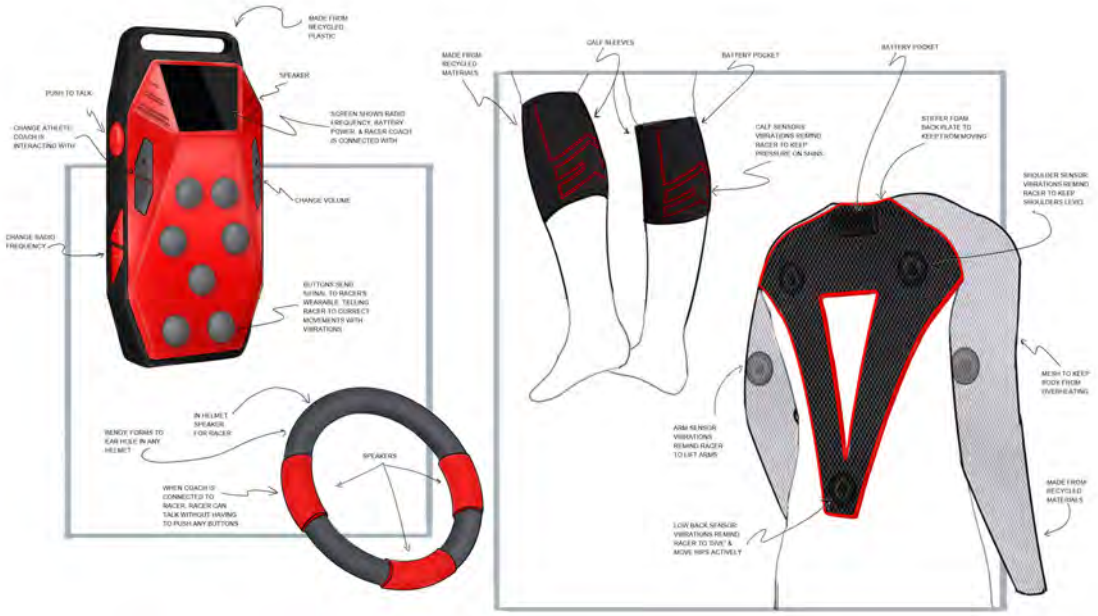


The ideations chosen to move forward with are circled. The main concept involves vibrating sensors that send vibrations to the racer's wearable through radio signals sent by the coach. The others circled are a helmet radio for each racer and sensors that track movement.

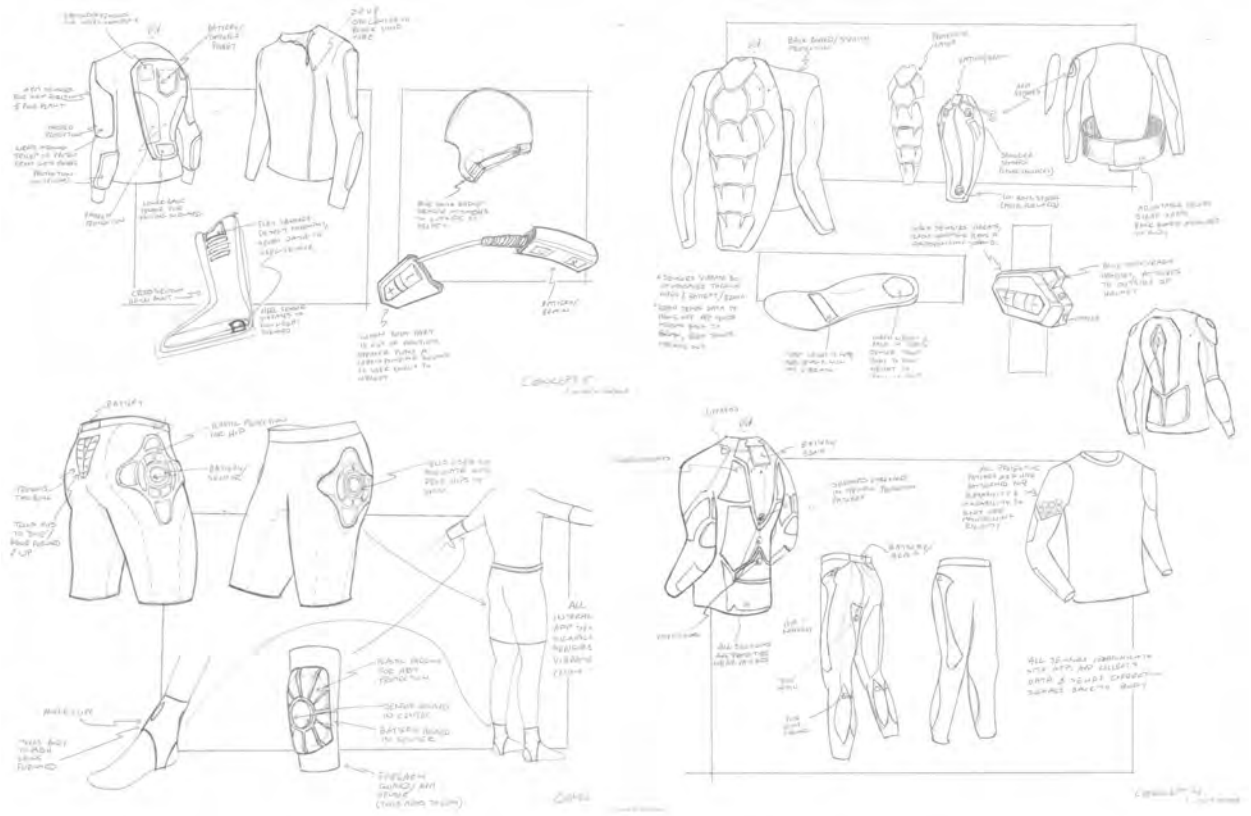
4.3 Concept Refinement

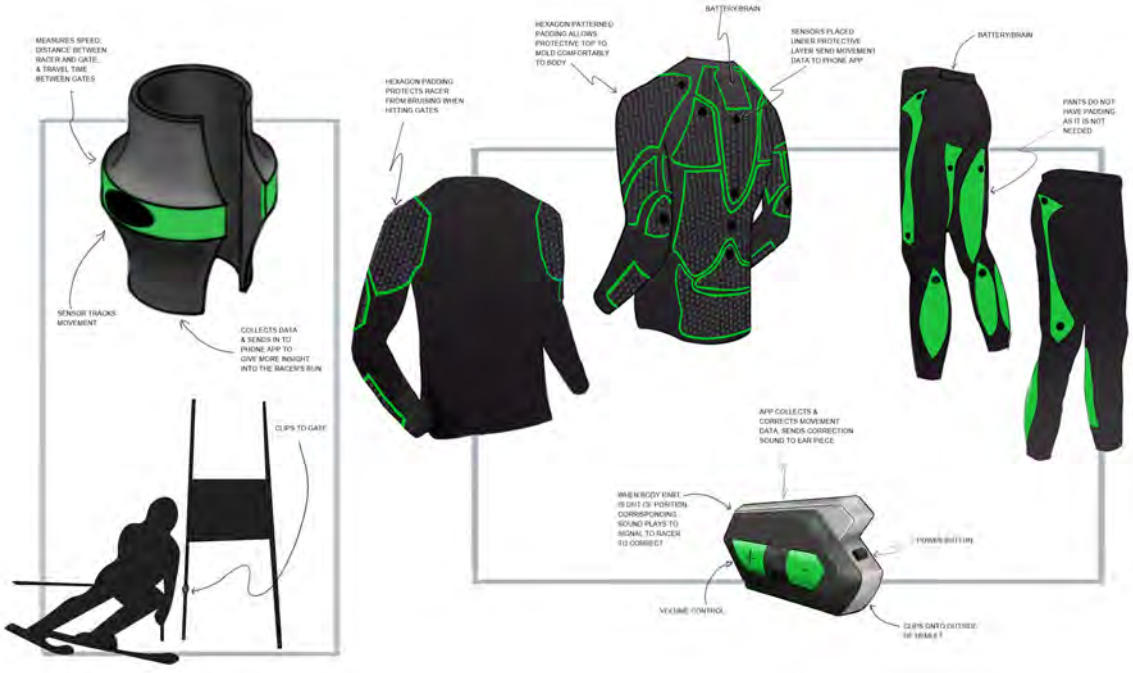
Concept 1





Concept 2

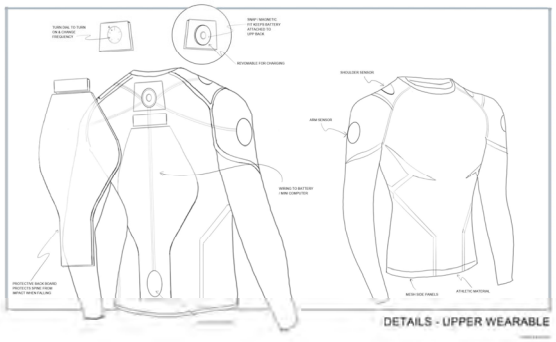


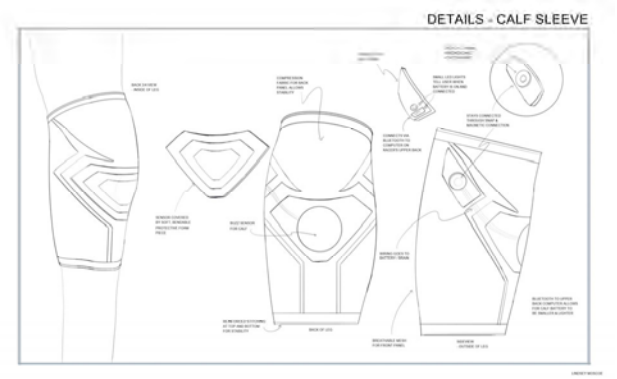

MEASURES SPEED, DISTANCE BETWEEN RACER AND GATE, & TRAVEL TIME BETWEEN GATES
SENSOR TRACKS MOVEMENT
COLLECTS DATA & SENDS IN TO PHONE APP TO GIVE MORE INSIGHT INTO THE RACER'S RUN
CLIPS TO GATE
HEXAGON PADDING PROTECTS RACER FROM BRUISING WHEN HITTING GATES
HEXAGON PATTERNED PADDING ALLOWS PROTECTIVE TOP TO MOLD COMFORTABLY TO BODY
BATTERY/BRAIN
SENSORS PLACED UNDER PROTECTIVE LAYER SEND MOVEMENT DATA TO PHONE APP
BATTERY/BRAIN
PANTS DO NOT HAVE PADDING AS IT IS NOT NEEDED
APP COLLECTS & CORRECTS MOVEMENT DATA, SENDS CORRECTION SOUND TO EAR PIECE
WHEN BODY PART IS OUT OF POSITION, CORRESPONDING SOUND PLAYS TO SIGNAL TO RACER TO CORRECT
POWER BUTTON
VOLUME CONTROL
CLIPS ONTO OUTSIDE OF HELMET

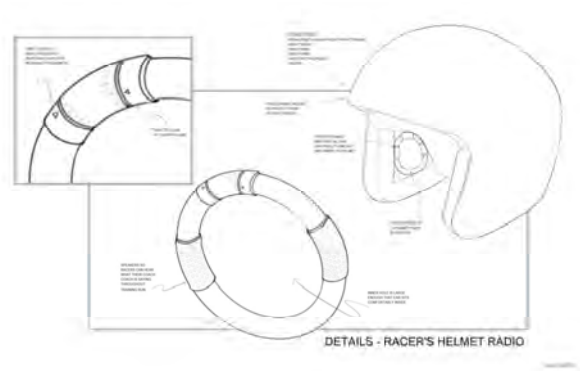
It was decided that elements of both designs would be combined to create the design solution. It contains vibrating sensor wearables and a radio ear piece for the racer, and a radio for the coaches that allows them to talk to each racer and send vibrations to the wearable of each racer.

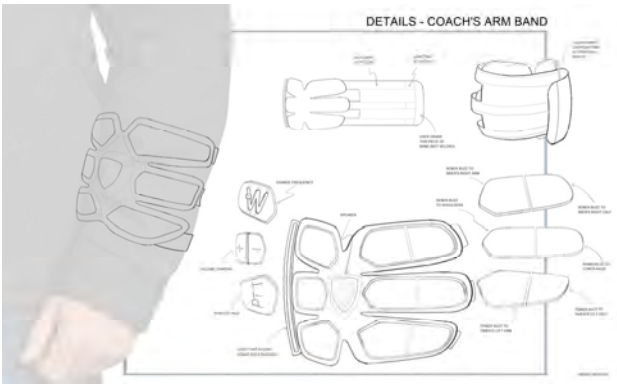
4.4 Detail Resolution

The detail sketches revolve around smaller elements of the design, such as the wearables' different layers, how the vibrating sensors are laid out, and how the coaching arm band comes together.







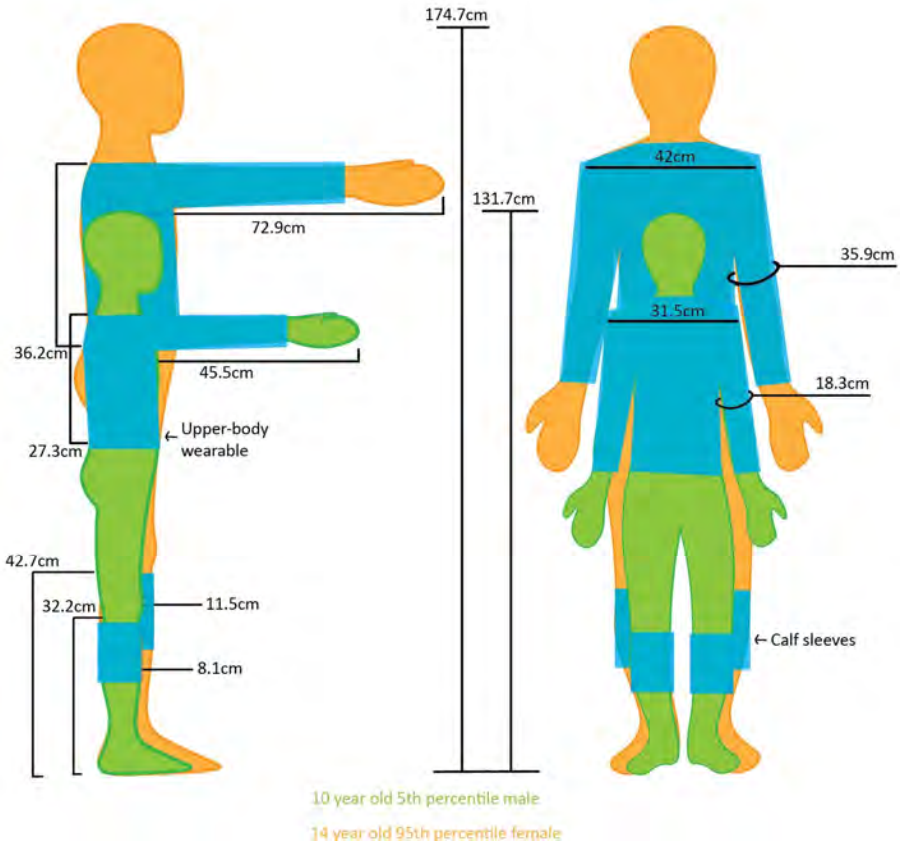


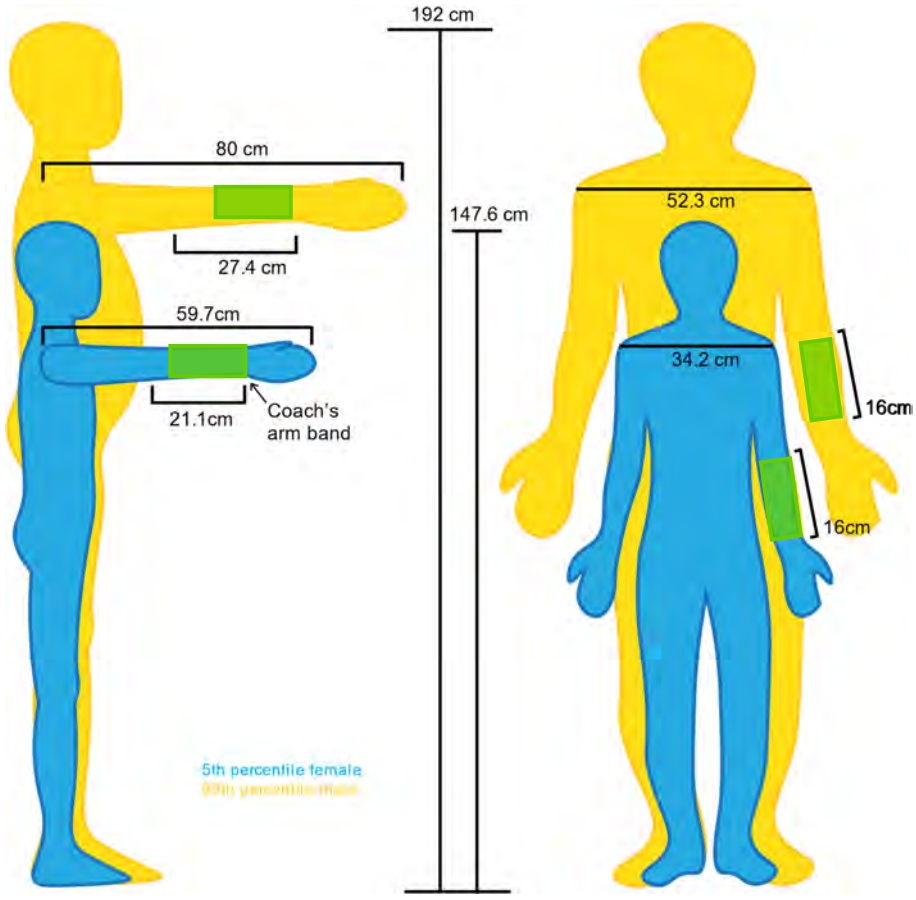
4.5 Sketch Models

4.5.1 Functionality

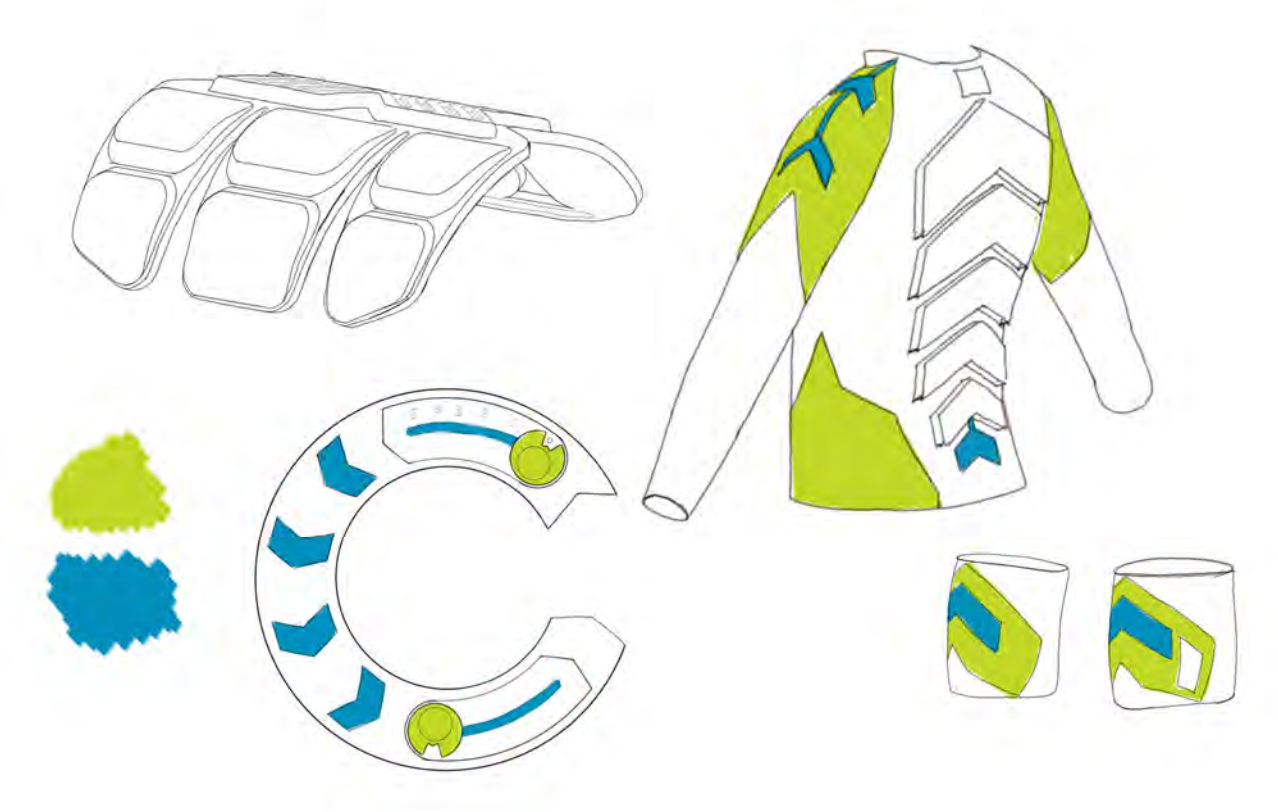
Scale models were created of each part to aid in the final design direction. These models helped with ergonomics and dimensioning for each part. For example, the coaching arm band was designed to be adjustable over any jacket and comfortable to use with bulky gloves or mittens. Additionally, the ear-piece sketch model revealed that the final design must be flat to fit into all helmets properly and comfortably.

4.5.2 Ergonomics





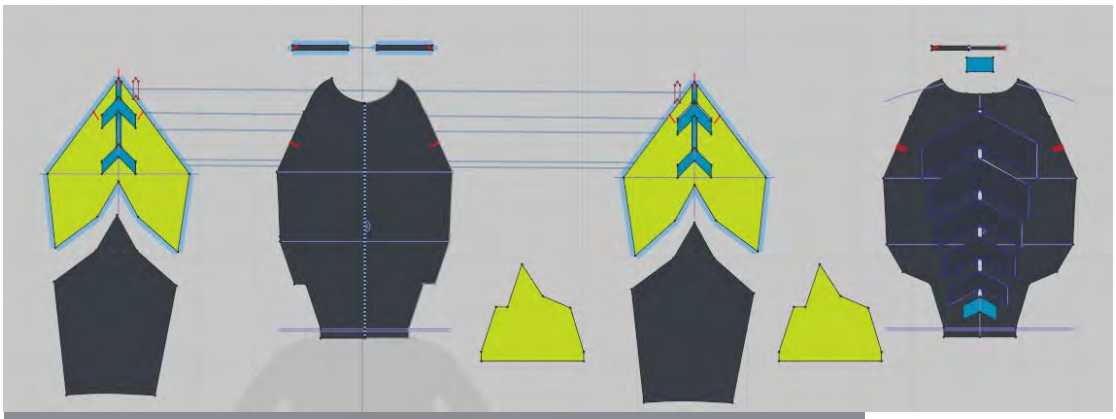
4.6 Final Design

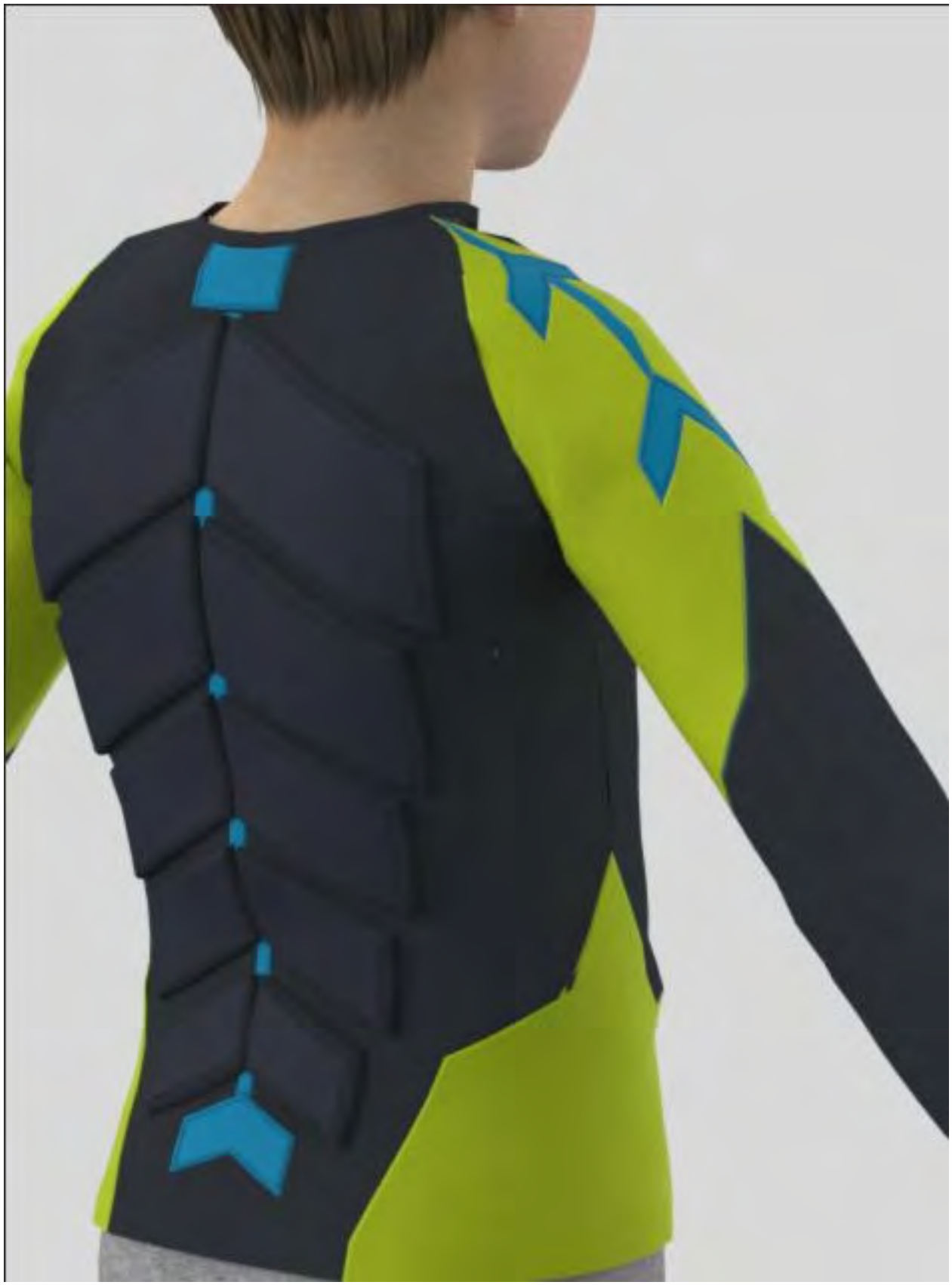


The final design consists of a shirt, calf sleeves, ear piece, and arm band. The shirt is worn by the athlete, has spinal protection, and vibrating sensors on the arms, shoulders, and lower back. The calf sleeves are worn by the athlete and have vibrating sensors on the back. The ear piece is also worn by the athlete inside the helmet, allowing coaches to communicate verbally with the athlete while skiing. The arm band is worn by the coach. It contains a radio that allows the coach to communicate with other coaches, athletes, and the vibrating sensors on the athlete wearabels. WGSN's trend forcasts helped guide the patterning and colourways (Varga, 2018).

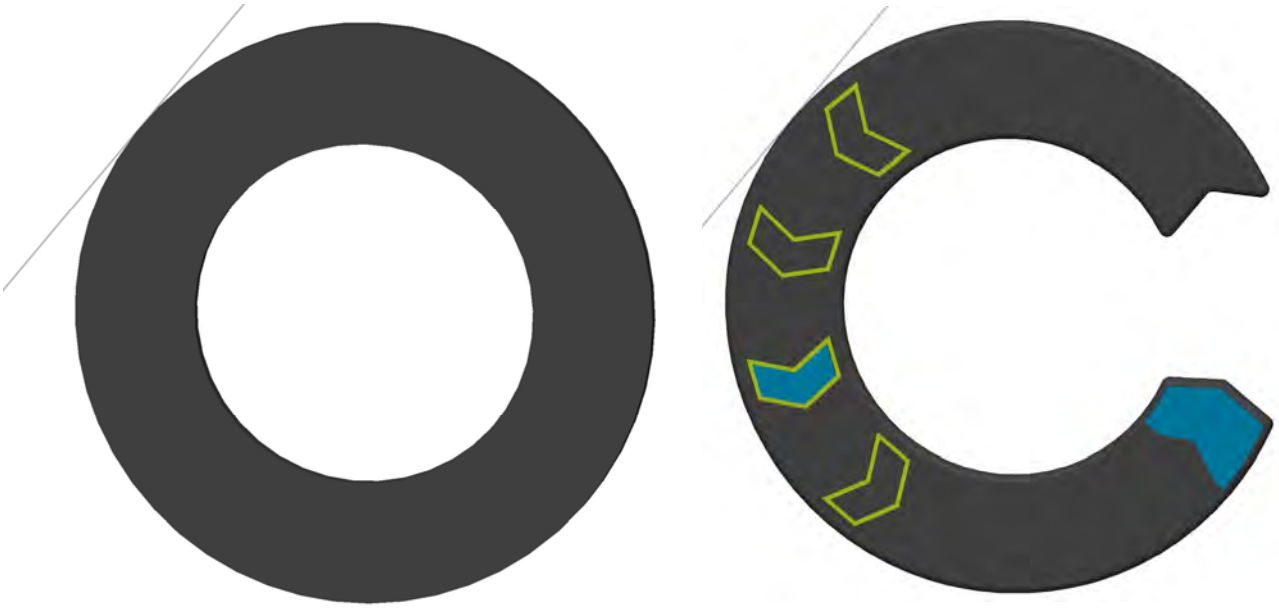
4.7 CAD Models

Racer wearable:

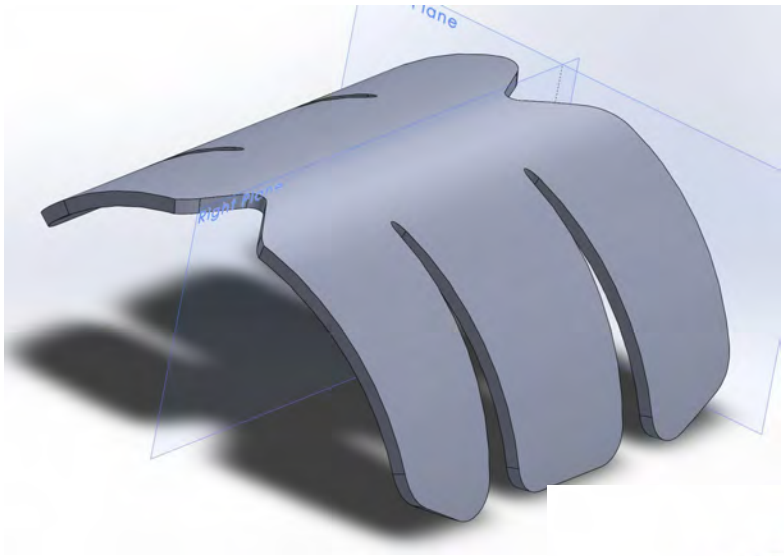


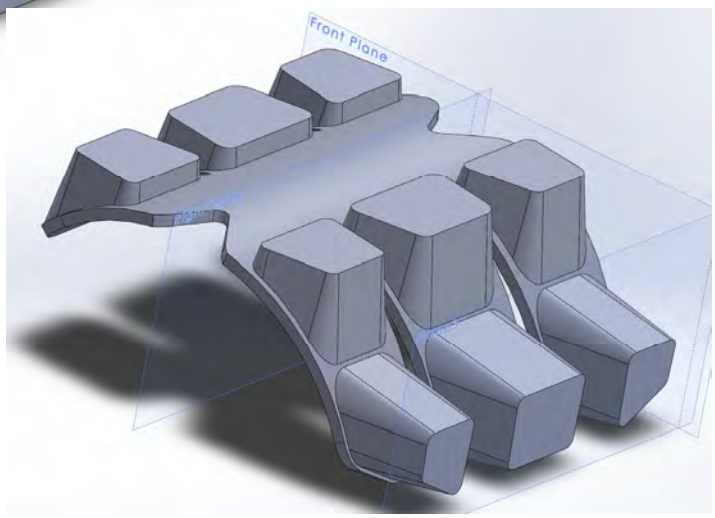


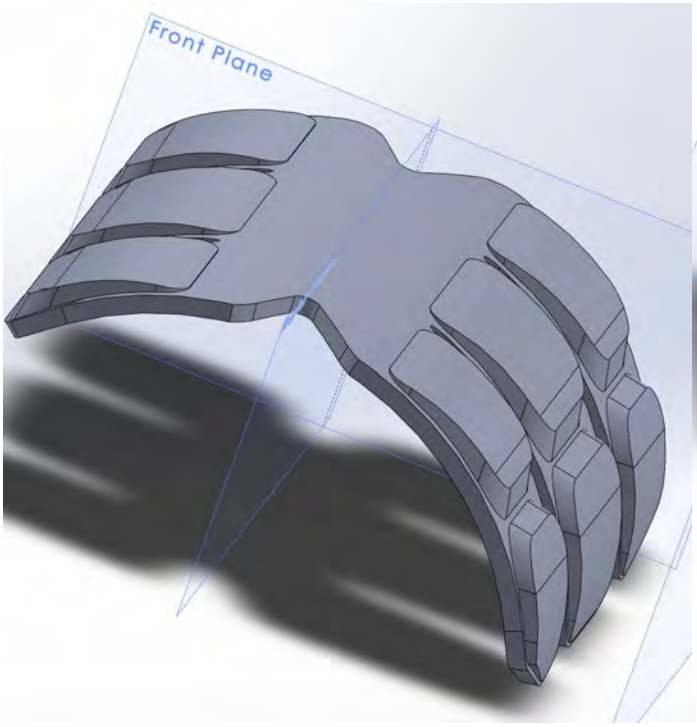
Racer in-helmet radio receiver:

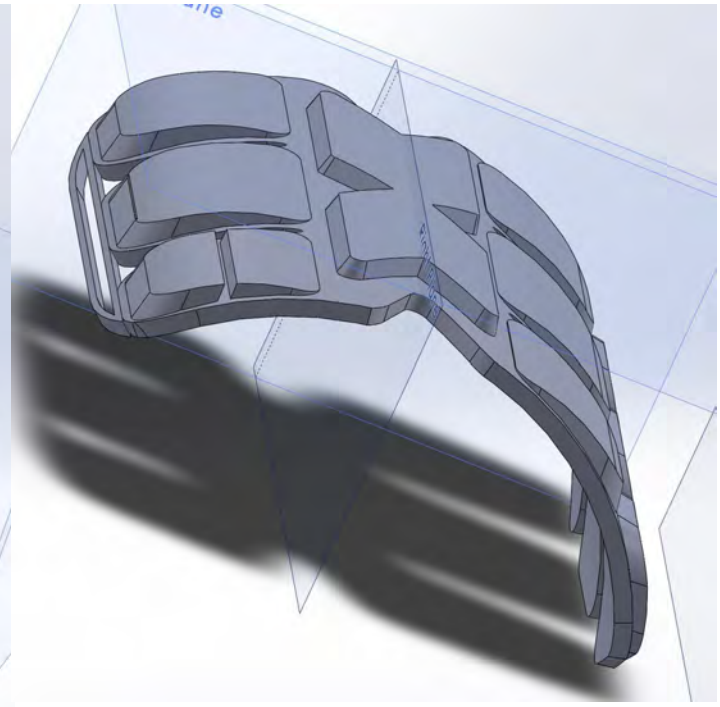


Coach’s arm band:

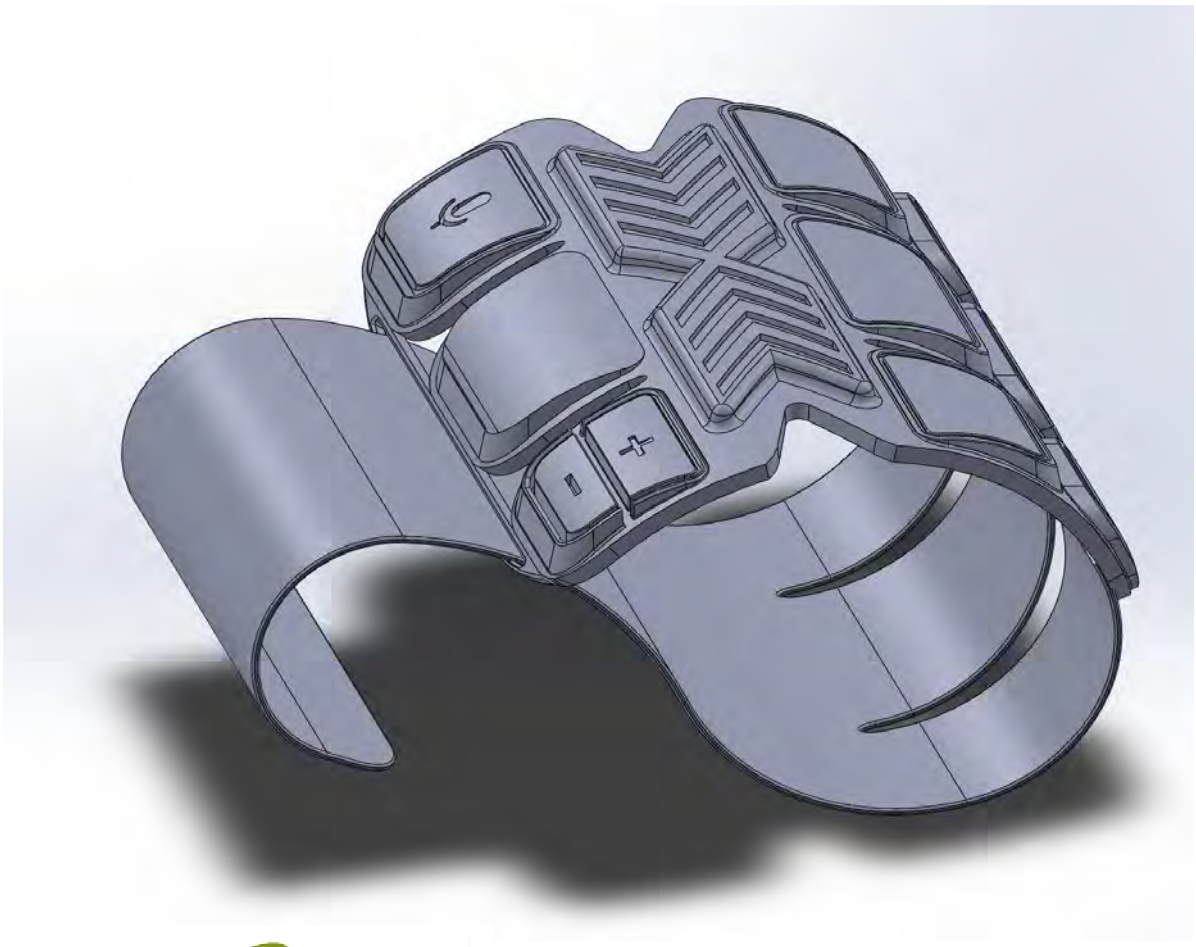




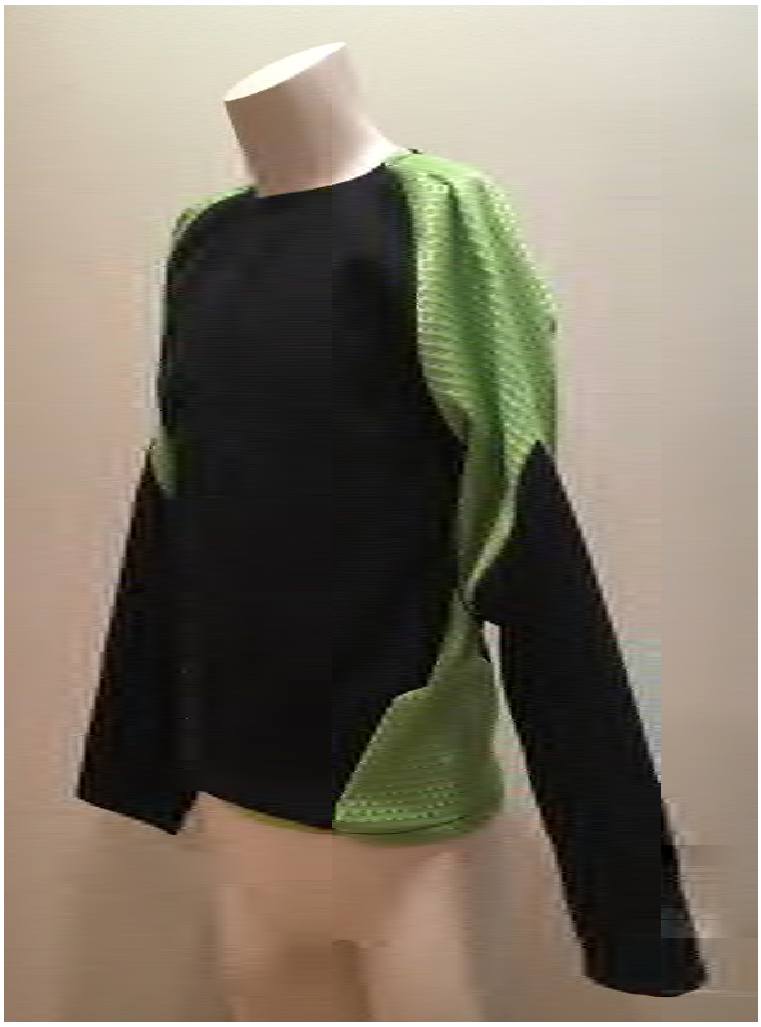

Front Plane

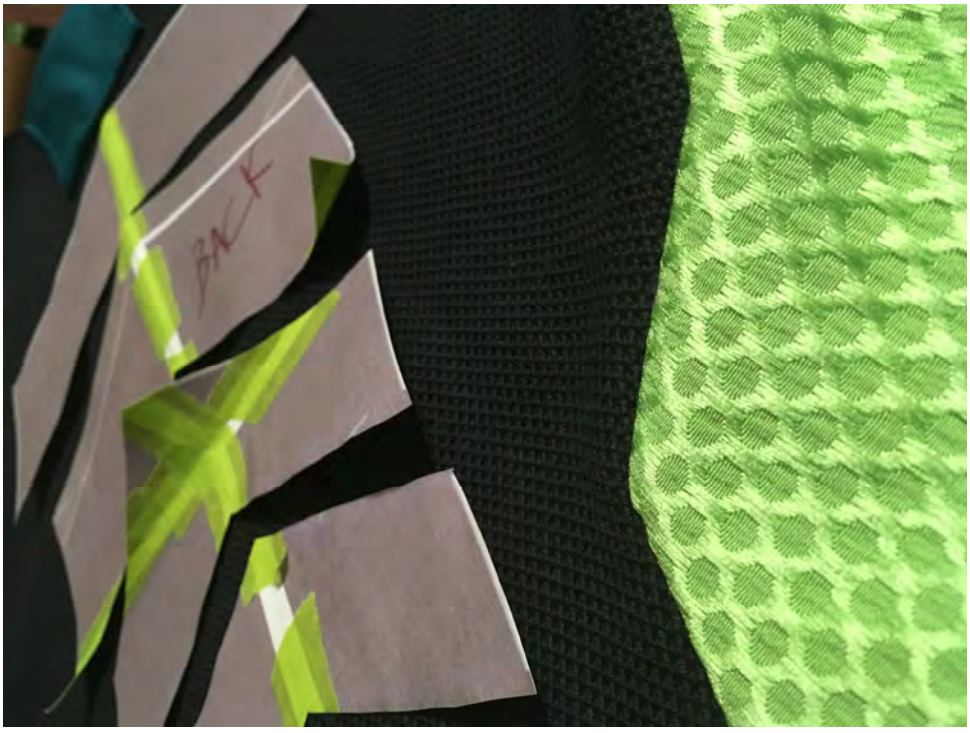



Front Plane



4.8 Hard Model Fabrication History




BACK

5 Final Design

This chapter discusses the final design of the ski race training system. It summarizes the design process, features, ergonomics, and more. It also includes a cost estimation, final CAD renders, and photos of the final model.

5.1 Summary

5.1.1 Description

Skade is a set of wearables designed to aid in ski race training. This system will lower communication barriers between coaches and athletes.

5.1.2 Explanation

There are currently no wearable training devices for ski racers. Current race training practices focus on verbal and visual communication, and repetition. The coach and racers stand at the top of the hill while the coach verbally explains what the racers are going to do. Then, the coach gives a demonstration. Unlike in other sports, the coach cannot talk while giving the demonstration, as the racers will not be able to hear them as they ski down the hill. Next, each racer goes down the hill one at a time and stops at the coach to receive verbal feedback. This can be a frustrating process for some racers.

Skade is designed to improve ski race training practices by improving communication between coaches and athletes. It consists of an upper body wearable, calf sleeves and radio ear piece for the racer, and a radio arm band for the coach. The upper body wearable and calf sleeves have vibrating sensors on the arms, shoulders, lower back, and calves. These sensors are attached to a battery and radio receiver, located at the upper back of the wearable. This piece is removable for charging and attaches into the pocket with a magnetic snap. The wires attaching the vibrating sensors to the battery connect together in the pocket in which the battery sits. This radio receiver connects to the coach's arm band. Each calf sleeve also has its own battery and radio receiver, which connects to the main receiver on the upper body wearable. To set off a vibrating sensor, the coach must press the corresponding button on their

arm band. The racer will feel the vibrations and correct their body position accordingly. The vibrating sensors are located on the shoulders, upper arms, lower back, and calves. The shoulder vibrations can tell the racer that they must level out their shoulders or that they need more upper body separation. The arm vibrations can tell a racer that they need to pole-plant more often, help with pole plant timing, or keep their arms in the correct position. The lower back vibrations are to help with movement and timing. The calf vibrations are to remind the racer to stay forward and to have strong shin pressure. In addition, the upper body wearable has spinal protection.

The radio ear piece sits flat around the ear inside of the helmet. It is controlled by two sliding dials. The first controls power and volume, the other controls frequency. The ear piece gives the coach a way to communicate with the racer while the racer is skiing. For example, if the coach presses the arm vibration button and the racer does not react, the coach can verbalize the instruction to the racer instead.

The coach arm band is the main control unit. Currently, coaches carry heavy-duty radios that they use to communicate with each other. Occasionally, a radio will be left at the top of a race training course that the racers are able to use to receive feedback before their training run. Additionally, if a coach wants to talk to a racer while they are skiing, the coach must ski very close to the racer and yell the instructions, or the racer must carry another coaches heavy-duty radio in their pocket and attach an extension to the top of their coat. Both of these options are dangerous, and it is still likely that the racer will not hear what the coach is saying. Skade's arm band is an ergonomic replacement for that radio. The arm band wraps around the lower arm outside the coach's jacket and is adjustable with a Velcro strap. It can be used on either arm. The arm band has six buttons that correspond to the vibrating sensors on the

racers' wearables: one button for the shoulder sensors, one button for each arm, one for the lower back, and one for each calf. While watching a racer, the coach will be able to send a vibrating signal to the racer so they can correct their positioning. The arm band is also a radio, allowing the coach to communicate with other coaches and their athletes. There is an easily accessible 'push to talk' button, volume buttons, and a frequency gear shift that also controls the power. These pieces all work together to create a new training experience for ski racing.

5.1.3 Benefit Statement

Skade benefits the athletes' skill development, and it can also reduce coaches' frustrations while teaching. Skade is a human centered, full body interactive system designed to narrow the communication barriers between coaches and athletes. Some specific benefits include the kinetic vibrating response system that sends a physical message to the racer, so they know what needs to change, and the ability for a coach to talk to a racer while they are skiing. Skade gives racers' the opportunity to receive more feedback in an easy to understand format. This will allow racers' to improve more quickly, gain confidence, and enjoy the sport more, which is beneficial for both the athlete and the sport.

5.2 Design Criteria Met

5.2.1 Ergonomics

Each part of Skade has different ergonomic requirements. Two pieces, the racer upper body wearable and the calf sleeves, use existing clothing measurements. However, the ear piece and the coach arm band are one size fits all. Many ergonomic requirements and anthropomorphic measurements were taken into consideration when designing these two parts.

The ear piece was designed to fit around the ear inside the helmet, flat against a child's head. It will not move in response to vibrations from the terrain or the racer's own movements.

The arm band was designed to fit over the jacket of anyone over the age of 16. The adjustable Velcro strap ensures that the arm band will fit over any jacket.

The calf sleeves were designed to fit the upper portion of the lower legs, so they do not interfere with the fit of the ski boots. The batteries are located on the outside of the legs, which is the least likely place for the batteries to break. The calf sleeves are sized like calf compression sleeves.

The upper body wearable follows regular clothing sizing. The spinal protection covers the whole back from the shoulder blades to the tail bone. The battery located on the upper back sits between the upper portion of the shoulder blades.

5.2.2 Materials, Processes, & Technologies

Upper body wearable and calf sleeves:

When in production, the upper body wearable and calf sleeves will be made from cotton and polyester fibres. Pratibha Syntax fabrics will be used. This company is vertically integrated, fair-trade certified, and makes sustainable textiles, including fabrics in the active-wear category (Pratibha Syntex, n.d.). They primarily use organic fabric, recycled polyester, viscose, and hemp (Pratibha Syntex, n.d.). This is appropriate for Skade, as the wearables must be comfortable to move in and be breathable. The wearable will be fabricated in two layers: the base layer, and the vibrating sensor and wire covers. The vibrating sensors will be held in thin injection molded cases, sewn between the two layers of fabric. These sensors will be attached through wires to the battery and radio pack. Lithium ion batteries will be used, as they are light weight and easy to charge.

Racer ear piece:

The ear piece will be made from Ingeo by NatureWorks (NatureWorks, n.d.). This is a plant-based plastic (NatureWorks, n.d.). This unit will be injection molded and snap-fit together around the radio receiver. As technology has progressed, radio transmitters and receivers have become very small. The smallest radio receiver has building blocks the size of two atoms (Burrows, 2016). This allows the unit to be light weight and sit flat against the user's head.

Coach arm band:

The coach arm band, like the ear piece, will be made from Ingeo. It will also be injection molded. The arm band will have radio transmitters and receivers placed inside the plastic casing. The back of the arm band will be covered in a soft foam layer which will cover the screw holes and reduce friction so it will stay in place on the coach's arm. The Velcro strap will be attached to the device between the plastic and foam layers. There will be a rubber tab sewed onto the end of the fabric to help the coach adjust the strap.

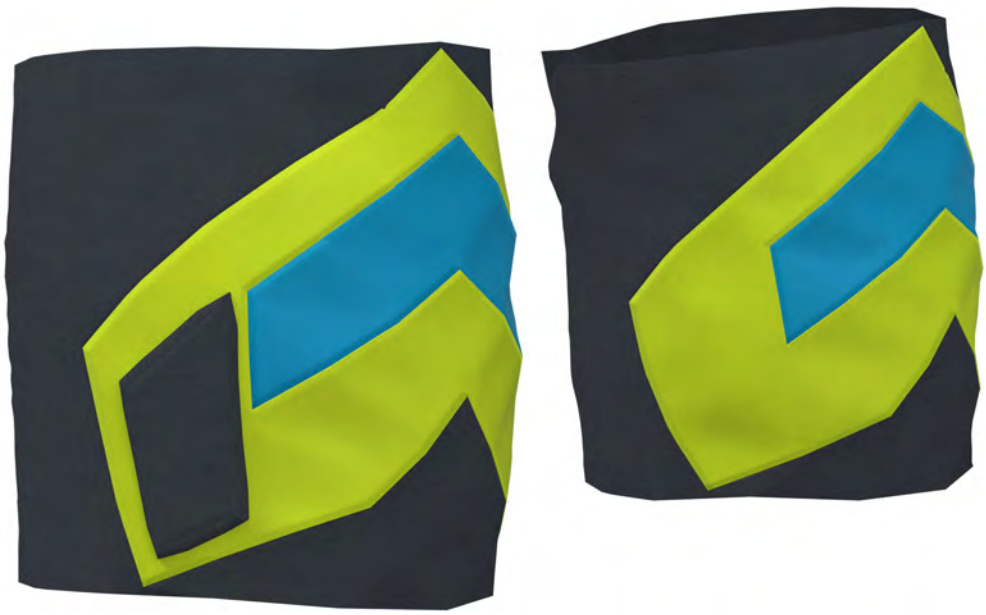
5.2.3 Manufacturing Cost Report

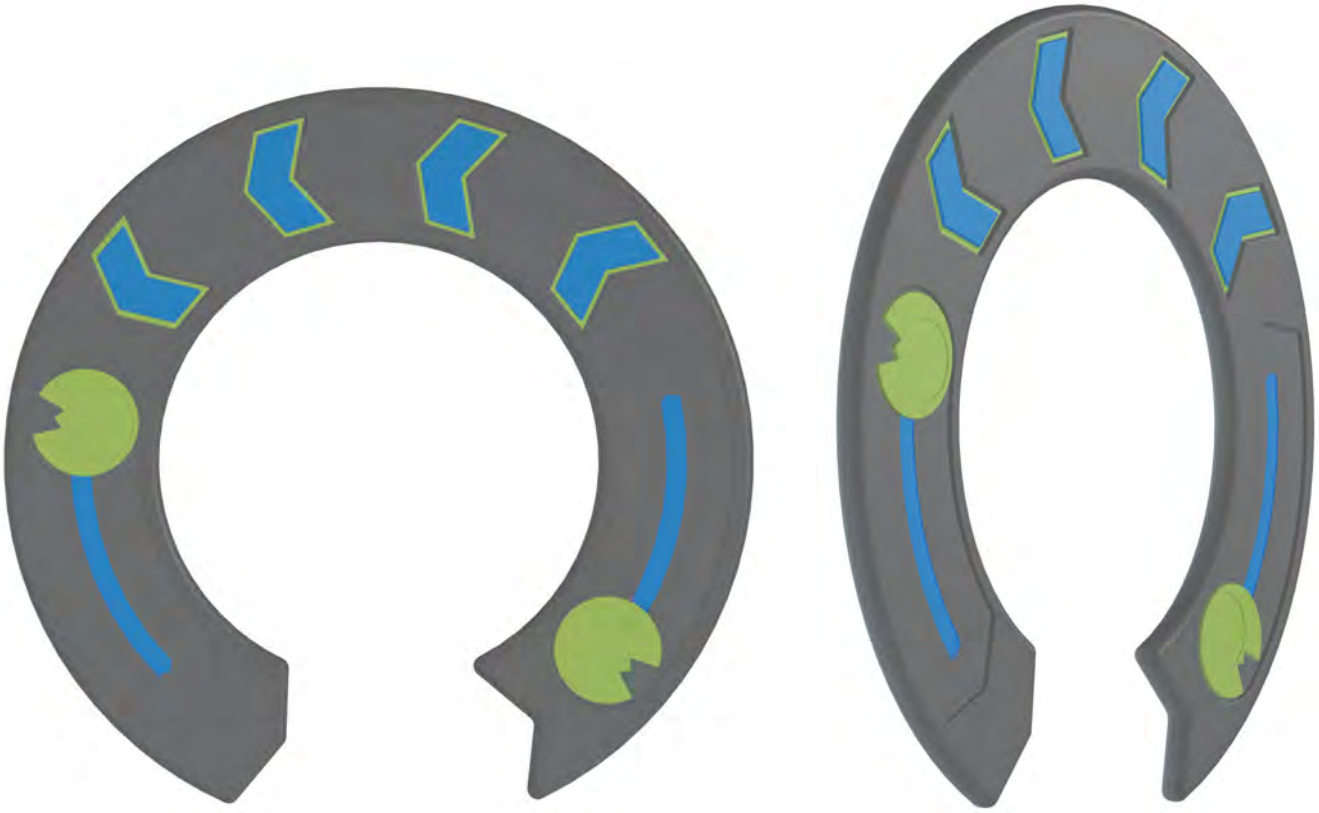
Part	Units	Cost
Calf sleeves	2	~$70
Calf battery	2	
Upper body wearable	1	$150 - $200
Sensors	7	
Upper body brain/battery	1	
Wiring	5	
Ear piece casing	1	$150
Ear piece dials	2	
Arm band casing	1	$200 - $250
Arm band buttons	9	
Frequency gear	1	

Arm band backing	1	
Velcro strap	1	

The costing is based off of existing products in each category.

5.3 Final CAD Renderings



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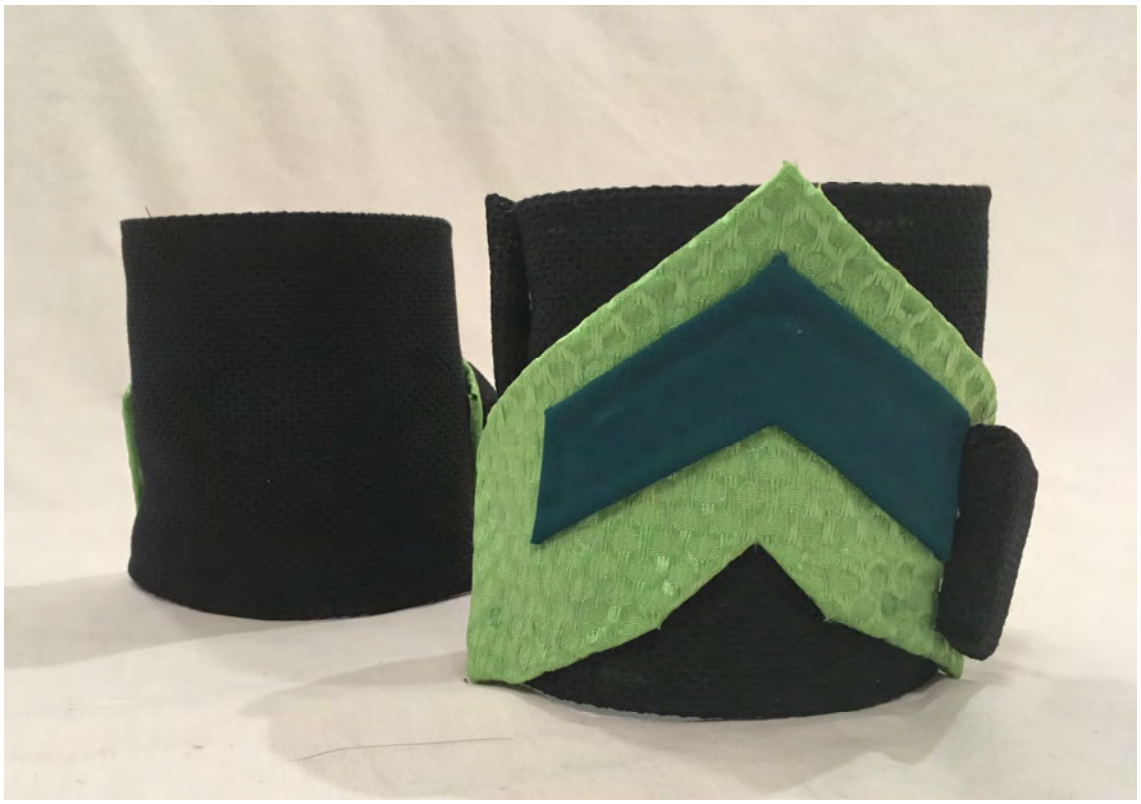
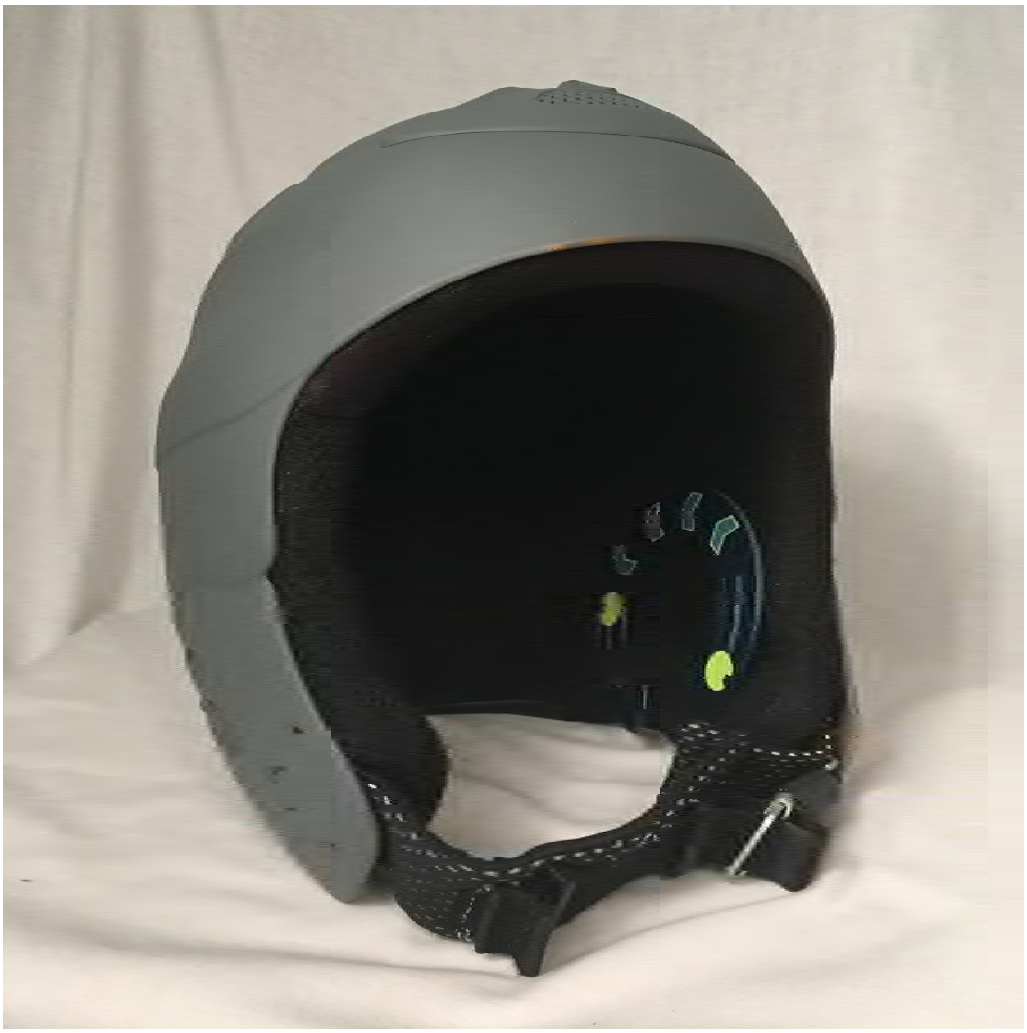
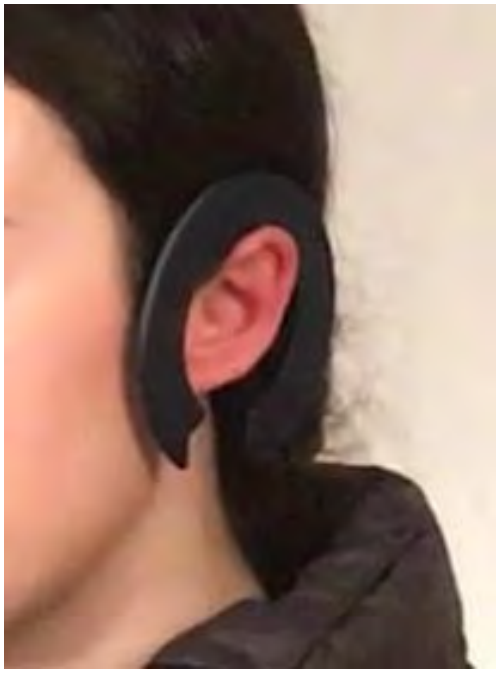
5.4 Hard Model Photographs

Racer’s wearables



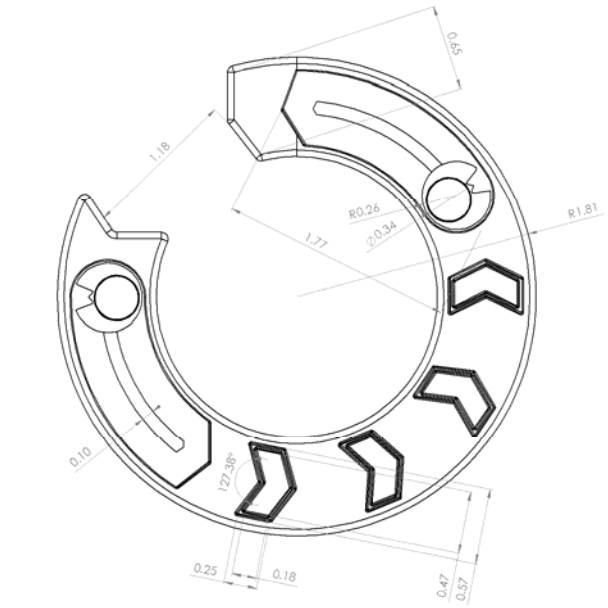
Racer’s ear-piece

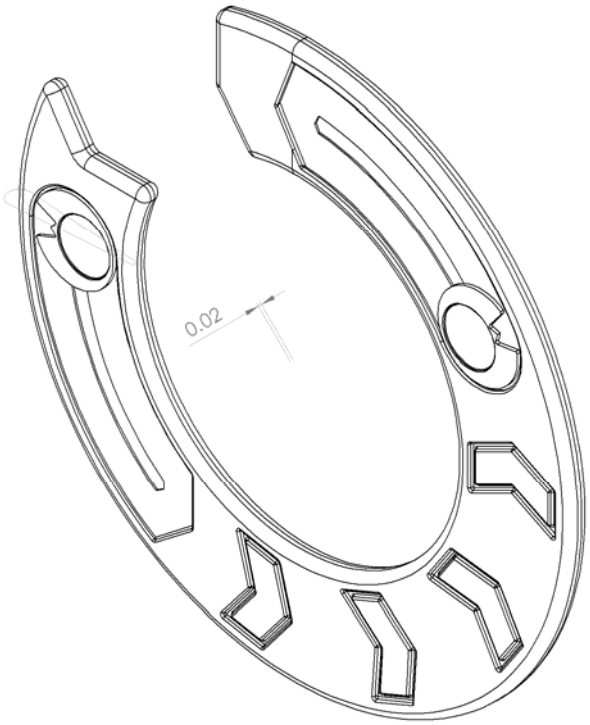


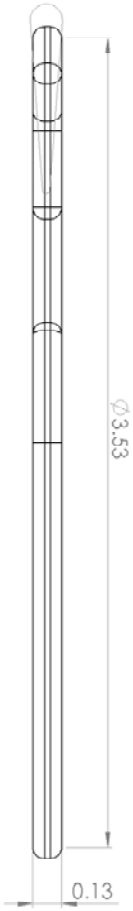


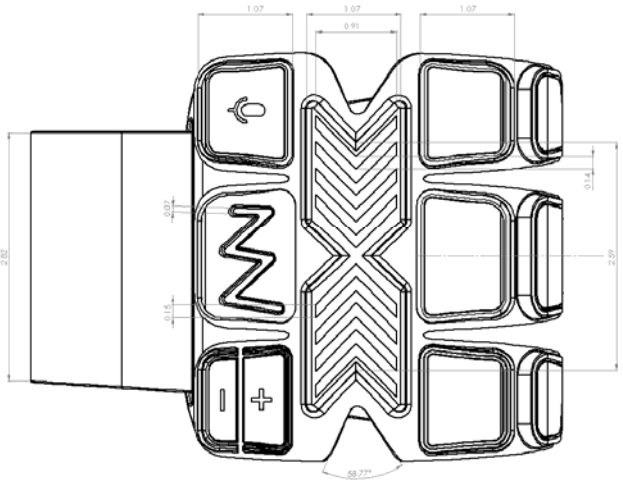
Coach's arm band (not painted due to COVID19)

5.5 Technical Drawings





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1.07
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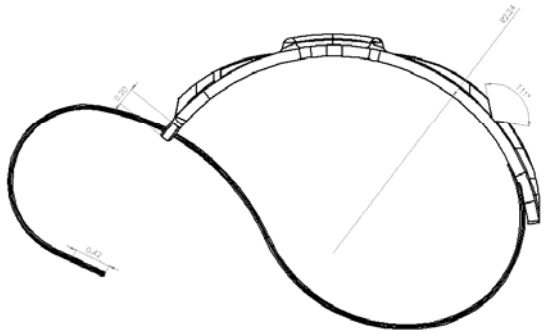
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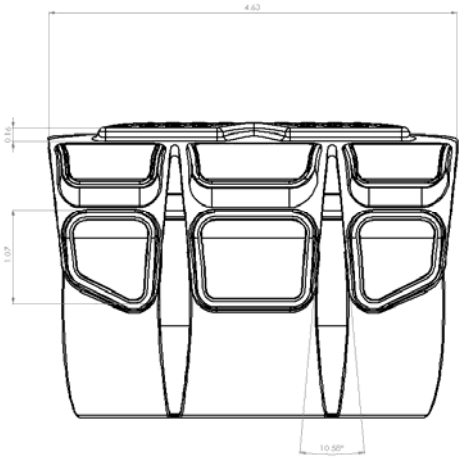
4.63
0.15
1.07
10.58°

5.6 Sustainability

The final design solution for this thesis is a human centered training device for ski racing. The final design will have sustainable aspects for user and environmental health and safety. The upper body wearable and calf sleeves will use Pratibha Syntax fabrics, as this company is vertically integrated, fair-trade certified, and makes sustainable textiles, including fabrics in the active-wear category (Pratibha Syntex, n.d.). They primarily use organic fabric, recycled polyester, viscose, and hemp (Pratibha Syntex, n.d.). An option for the threading is Natura thread. This thread is made from 100% cellulose fibers, organic cotton, or a biodegradable polymer (Johann Muller AG, n.d.). Their materials are also dyed with a Cradle to Cradle assessed dye chemicals (Johann Muller AG, n.d.). The plastic that will be used for the final product is Ingeo by NatureWorks (NatureWorks, n.d.). This is a plant-based plastic, however the company is, "…assessing new technology to skip plants and use microorganisms to directly convert greenhouse gases…" into plastic (NatureWorks, n.d.). See Appendix X for more information.

6 Conclusion

Skade is a device that improves training for young ski racers. It reduces communication barriers between coaches and athletes by using auditory and kinetic communication simultaneously. This allows racers to receive feedback while actively skiing and which will enable them to improve more quickly.

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8 Appendix

i Discovery

Preliminary Information Search

The objective of this report is to assess the feasibility of perusing a thesis project on how to help develop ski racers between the ages of 10 and 14. Peer-reviewed sources were used.

Search Topic
How may we aid in the development of ski racers between the ages of 10 and 14?

Background
This proposed thesis is to help young alpine ski racers develop.

Needs Statement
Currently there are no tools specifically designed to help with the growth and development of skills in young ski racers.

How is this need being addressed currently?

Currently, the development of ski racers is done through drills. Drills are repetitive physical movements designed by coaches to teach specific skills. Drills are explained verbally and/ or demonstrated by the coach. The coach explains a drill, and the youth racers try to do it. This can work for older racers who understand how their body works and who can make adjustments from verbal feedback. However, young racers do not know what certain movements are supposed to feel like, so they do not understand verbal feedback as well. Additionally, many drills that are used require the skier to be physically strong. If the young skier is not, they are at higher risk of injury as they do not understand how to use the muscles they have properly yet.

Key Article 1

Method
A key article for this topic was sourced and selected. Required article content (Abstract, Introduction, and Discussion sections) were copied and highlighted.

Search Engine: Humber Library Discover

Key Words Used in Search: “ski racing skill development age 10 to 14”

Findings
Citation: Raschner, C., Hildebrandt, C., Mohr, J., & Müller, L. (2017). Sex Differences in Balance Among Alpine Ski Racers: Cross-Sectional Age Comparilosons. Perceptual and Motor Skills, 124(6), 1134–1150. doi: 10.1177/0031512517730730

Summary Statements

1. Balance is affected by age and maturity
2. Balance affects performance and injury prevention

3. Ski racers must show muscular strength and power, balance, and agility as ski racing demands lateral and forward-backward balance over changing terrain.
4. Ski racers are exposed to low temperature during training and races. This affects the nervous system and physical and cognitive performance, which decreases postural control and increases injury risk.
5. The data found in this article can aid in training athletes in the use of new ski technology, balance, neuromuscular efficiency, "and the effectiveness of their proprioceptive, visual, and vestibular systems"

Key Article 2

Method
A key article for this topic was sourced and selected. Required article content was copied and highlighted.

Search Engine Used: Humber Library Discover

Key Words Used in Search: 'ski racer development age 10 to 14'

Findings
Citation: Steidl-Müller, L., Hildebrandt, C., Müller, E., Fink, C., & Raschner, C. (2018). Limb symmetry index in competitive alpine ski racers: Reference values and injury risk identification according to age-related performance levels. Journal of sport and health science, 7(4), 405–415. doi:10.1016/j.jshs.2018.09.002

Summary Statements

1. There is a significant difference in the limb symmetry index in the three age-related performance-level groups in strength related tests.
2. Younger athletes have a higher LSI in strength tests.
3. Differences in limb strength heightens the risk of injury in youth ski racers.
4. A high lower limb symmetry index is a strong predictor for injuries.
5. The risk of sustaining an overuse injury is higher during a growth spurt.
6. Growth spurts change body composition and may increase the development of imbalanced limbs, which can increase injury risk.
7. The younger the athlete, the more likely it is that their limbs are asymmetrical.

Expert Interviews

Interview One: Racer
Method: Phone interview transcription

Questions and answers.

1. Have you ever had any issues with communication while training?
   A: Yes. When teams are big and there are a lot of other people around it's hard. It also depends on the coach. Like some coaches only focus on the top few kids on the team and then the second coach is left with everyone else. So it's not always fair and not everyone

gets the same attention.

2. How do your coaches communicate with you?
   A: I learn better when they show me than if they just tell me. Like if they want me to understand something they have to do it. Some just describe what they want.

3. Have you ever had trouble trying to translate what a coach tells you into movement?
   A: Sometimes, but usually if I don't understand I tell them I don't understand and they tell me again.

4. Has a coach ever changed the way they explain a concept to help you understand it better?

   A: Yes, multiple times. If it's really confusing and I don't understand it they put it in different words to try to explain it.

5. How do coaches explain a basic concept like movement or being on the downhill ski?
   A: They say stuff like 'try to put your hands more down the hill, and move your body facing down the hill while your hips move into the snow making a C shape." They tell me how to move my body and what it's supposed to feel like. Or they just show me how to do it.

6. Are there terms that coaches use that young racers may not understand?
   A: Skiers left and skiers right took a while for me to understand. If I don't understand a term I figure it's not important.

Interview Two: Coach
Method: Phone Interview transcription

Questions and answers.

1. Have you ever had issues communicating with a racer?
   A: Yeah, there's a lot of times where young kids don't understand. Majority of them don't. There's a very small percentage that understand what you are trying to convey. What I always do is ask them if they understand, and 9 times out of 10 they go "yeah I totally understand," and then I ask them to explain it back to me, and they explain it back but it's wrong. And then you explain it to them in a different way. You kind of come down to their level, meet in the middle so they can grasp the point you're trying to explain to them. Asking a lot of questions to them gets them to understand a little bit better.

2. If a racer does understand a concept and they explain it back to you properly, do they ever have problems translating it into movement?
   A: Yes. It's especially difficult because everyone learns differently. There's going to be those people who pick it up through explanation, and there's going to be those kids who, I could explain it every which way but sideways, and they won't get it, but if I show them they get it. There's always kids who do understand it but can't make their bodies do it.

3. How would you describe a basic concept like movement or for-aft balance to a racer?
   A: For for-aft I use the words pressure, release, balance, bend your knees, push on the front of your boots. One thing I always use is step down on the balls of your feet and push down on your toes. And they're like "Oh! Now I get it!" One thing I'm really big about is making sure that they understand what puts them into the position I want them in. You can't use terms like a FIS racer with a U10 racer, so you just say simple things.

4. Are there terms used a lot in coaching that younger racers don't understand?
   A: One term would be pressure on the downhill ski. Trying to explain that to a 10-year-old is hard. Now that I'm thinking about it I can't even remember what I usually say! There's obviously a lot of drills that you use to give them that feeling. So many times I catch myself starting to say "you've got to put pressure on the downhill ski," but I try to not say it because they don't get it, they don't know that feeling. What I do is try to put their body in the position. So I get them to stand on the hill and put them in the position of how I want the turn to be. So where are their hands, where are their hips. That's not necessarily saying pressure on the downhill ski, but it puts them in the position which in turn, they don't realize it, is putting pressure on the downhill ski. Getting them to do drills that give a certain feeling and explaining the result or feeling they will have helps explain concepts without actually using the words.

Interview Analysis

The interviews provided insight into how athletes and coaches perceive communication with each other. The athlete and coach that were interviewed both said that they recognize that people have different learning styles. Three learning styles discussed are visual, auditory, and kinetic. For example, the racer said that he is a visual learner and prefers to see demonstrations. The coach also said, "…if I show them they get it." Auditory learners understand verbal instructions best. However, the racer said that sometimes he does not understand what a coach is saying and asks for further explanation. Sometimes this is not enough, and he needs a visual demonstration. The coach recognizes that it is her responsibility to communicate clearly and help the racer understand what she is saying. She said that she often asks racers to explain concepts back to her so she knows that they understand. If they cannot do it, she re-explains the action a different way or shows them. She finds that for some children kinetic learning is most effective. She has the racer stand sideways on the hill and physically puts their body into the position she wants them to achieve while in motion so they can feel it. These three methods of communication can inform the product's design.

ii User Research

User Profile

Demographics

The method used to find the following images and quotes were key word searches through Google and the Humber College Library. Words that were searched were "U12 ski racer training gates," "U14 ski racer," "alpine ski race training," and "ski racing development."

Evidence: Literature Search

"Alpine racers must show high levels of aerobic and anaerobic capacity, muscular strength and power, and such complex motor abilities as balance and agility. Modern ski racing techniques demand a strong sense of lateral and forward–backward balance because of the extensive inward leaning body angles" (Raschner, Hildebrandt, Mohr, & Müller, 2017).

"… [M]aintenance of balance under challenging strength situations is critical for elite performance and injury prevention" (Raschner, Hildebrandt, Mohr, & Müller, 2017).

"…[A]thletes are normally exposed to low temperatures during ski training and racing situations, which affect the nervous system as well as physical and cognitive performance. Reduced sensitivity of the mechanoreceptors in the skin and muscles of the feet causes hypothermic anesthesia and therefore, partially impairs the ability to maintain postural control" (Raschner, Hildebrandt, Mohr, & Müller, 2017).

"Limb differences in unilateral leg extension strength represent a significant injury risk factor in youth ski racers" (Steidl-Müller, Hildebrandt, Müller, Fink, & Raschner, 2018).

"The risk of sustaining...overuse injuries is intensified during the adolescent growth spurt, and late-maturing athletes might be at a higher risk for both overuse and traumatic injuries... Additionally, during periods of rapid growth, changes in body composition may increase the development of imbalances, which could lead to an increased risk of injury… [C]hronological age has been shown to be a significant predictor of limb asymmetries in youth and adolescent athletes between the ages of 8 and 17 years, with younger athletes showing greater asymmetries compared with their older, more experienced counterparts" (Steidl-Müller, Hildebrandt, Müller, Fink, & Raschner, 2018).

"…[C]oaches are advised to develop a symmetrical strength capacity in both legs starting at an early age" (Steidl-Müller, Hildebrandt, Müller, Fink, & Raschner, 2018).

"The purpose of a strength and conditioning program for alpine skiers is to maximize lower-body strength, explosive power, a focus on low-velocity (primarily eccentric) force production, and developing the anaerobic metabolism, specifically developing the lactate threshold and lactate tolerance" (Hydren, Volek, Maresh, Comstock, & Kraemer, 2013).

"The relative age effect (RAE)…[is] an over-representation of selected athletes born early in the selection year" (Müller, Müller, Hildebrandt, Kornexl, & Raschner, 2015). RAE is a "…developmental advantage, which leads to a much broader experience in training and competition, and a resulting higher level of performance …physical and mental advantages...[R]elatively older athletes are often taller and heavier, which is beneficial in…alpine skiing…[T]he athletes selected for elite squads (who are most often relatively older) have better training facilities and higher qualified coaches, whereas the relatively younger ones often are not included in the talent development program; they do not have the same training possibilities, even though they are on average as talented as the relatively older athletes. As a consequence, the advantages of the relatively older athletes would increase… and many talented

young athletes are forfeited because they drop out of a sport early" (Müller, Müller, Hildebrandt, Kornexl, & Raschner, 2015).

Table 2
Anthropometric measurements of competitive alpine skiers in descending ages and level

Source	Age (y)	Level (as reported)	Men				Women			
			N	Body fat (%)	Height (cm)	Weight (kg)	N	Body fat (%)	Height (cm)	Weight (kg)
Emeterio and Gonzalez-Badillo (10)	M: 14.6 ± 1.1 F: 14.9 ± 1.0	Spanish Junior Development	15	10.2 ± 3.5	167 ± 10	59.2 ± 7.9	15	19.2 ± 3.4	159 ± 10	53.0 ± 6.4

M = male; F = female.

Table 1- Anthropometric measurements of competitive alpine ski racers aged 14 (Source: (Hydren, Volek, Maresh, Comstock, & Kraemer, 2013).

Conclusions

The information gathered from the image and literature searches give insight into the demographic group. The primary user is the young ski racer and the secondary user is the coach. The targeted age group is skiers between the ages of 10 and 14. Athletes at this age are just beginning to build muscle. They are also going through puberty and major growth spurts, which cause dramatic changes in body composition that are difficult to adjust to. Alpine ski racers must also have high levels of aerobic and anaerobic capacity, muscular strength and power, and balance and agility. These are important as they help the racer achieve their goals and help to reduce the risk of injury. Additionally, research shows that 14 year old athletes are often between 4'9" (shortest female) and 5'8" (tallest male) in height, have a weight between 117 pounds (lightest female) and 131 pounds (heaviest male), and have a body fat percentage between 3.4% (lowest female) and 19.2% (highest female).

Coaches do not belong to a set age group. A coach can be anyone over the age of 14 who has been certified by the Canadian Ski Coaches Federation. Their job is to teach the athletes proper ski racing technique. They do this through verbal instructions, video, and drills.

User Behaviour

The method used to find the user behaviour evidence was collected by using key word searches through Humber College Library, Google Scholar, and Google searches. Key words searched were "how often do youth ski racers train off snow," "ski race training," "ski race youth," "Canada ski areas map," and "ski racing motivation."

Evidence

"The schedule of a training day includes 1–4 warm-up runs, 1 inspection run of a training course, with 3–8 training runs on the course and 0–4 additional runs to help maintain the snow conditions on the course. Thus, training sessions last 2–4 hours with a total of 4–14 runs. A ski run can last from 1 minute to 10 minutes in duration with a rest break of riding a chair lift lasting for 5–15 minutes… [S]ome alpine training centers have installed ground lifts (T-bars and pama (sic) lifts), which increase the number of runs per session…[As these] runs tend to...[have]... less vertical drop than chair lift access training centers, these typically will involve a high percentage of aggressive skiing per meter of vertical drop. It is also not unusual for athletes to do 2-a-day sessions, especially for youth athletes on weekends or during training camps" (Hydren, Volek, Maresh, Comstock, & Kraemer, 2013).

"Alpine racing has changed drastically since the 1980s, including significant advances in equipment and increases in speed associated with elevated technical, physical, and potentially psychological demands required of the athletes" (Kiemle-Gabbay & Lavallee, 2017).

"High-risk sport athletes, including snow-sport athletes, cope with risk as an ever-present stressor during training and competing…" (Kiemle-Gabbay & Lavallee, 2017).

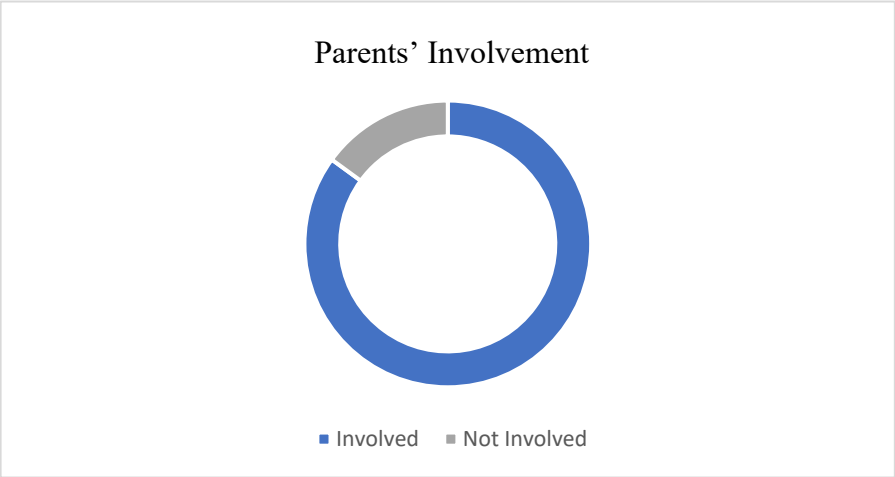
"Skills and abilities learned in dryland sports can be directly transferred to skiing…Key sports such as gymnastics, athletics, hockey, soccer, lacrosse, swimming, baseball/softball, ice skating, basketball, skateboarding, mountain biking, and trampoline will help young skiers acquire basic skills" (Alpine Canada Alpin, n.d., p.21-22).

"It is evident that most top skiers are good at many sports. Due to the nature of ski racing, it is imperative that a child is exposed to a cross section of other sports throughout the year. Physical abilities and superior fitness are the king pins of confidence" (Alpine Canada Alpin, n.d., p.23).

Quote from a World Cup alpine racer: "…Up until I was 14, I trained four to five days a week. I lived close to the hill and we had great night skiing… I hated losing races… I had the confidence to attack from when I was very young…I always had a good coach and did many interesting things in training. My mom and dad were always very involved…Winning was always the reward that pushed me…" (Alpine Canada Alpin, n.d., p.6).

"…As an athlete, you kind of live in your little bubble and you have this team around you. You want to be a good teammate, but ultimately, it's you on your own…" (Alpine Canada Alpin, 2019).

"Financial sacrifice is high barrier to entry/continuation" (Leever Partners, 2016). Of 127 World Cup athletes surveyed "85% of parents were involved when athletes decided to pursue the next level" (Leever Partners, 2016).



T able 2- Data from An Analysis of Alpine Skiing 2016.

Figure 4: A map of all the ski areas in Canada (Percoski, n.d.)

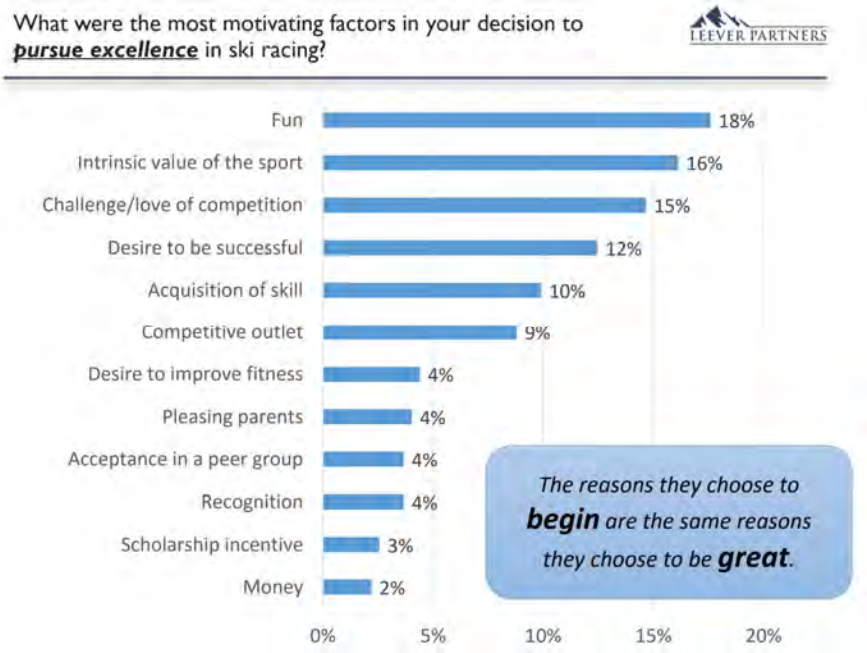


Table 3- Data from An Analysis of Alpine Skiing 2016.

Conclusions

The information gathered in this search helps explain user behaviour. The frequency of the activity differs depending on the location. For example, if the racer trains in southern Ontario on a hill, they are likely to be on snow two to four days a week between mid-December and mid-March. However, a racer who trains in British Columbia on a mountain will have access to training two to six days a week from mid-November to mid-April. Also, the average gate training period lasts between two to four hours, and the whole training day lasts between five to seven hours. As Figure 4 shows, there are many ski resorts in areas of Canada that are not mountainous. There are around 55 ski areas just in Ontario. As the ski season is not long, it is

important for athletes to continue to develop skills and strength, and maintain fitness, by participating in other sports and physical activities. There is also a significant mental component to ski racing which must be acknowledged and managed. Athletes are motivated by improving their skills and heightening their chances of doing well in races. They are also motivated because they are having fun while skiing and training. In addition, while alpine skiing is an individual sport, skiers train as a team and support each other. They receive encouragement from the rest of their team, coaches, and parents.

Money is also a concern, as skiing is an expensive sport. The parents of the athletes have the purchasing power. They buy the gear and pay for the coaches. Parents are also involved in the development of these athletes.

User Profile/Persona

Primary User: Ski racer Secondary User: Ski coach

Demographics		User behaviour	
Age	10-14	Frequency	2-6 days/week from Dec. – Apr.
Gender	All genders	Duration	5-7 hrs/day
Stage of life	Puberty	Social/solidarity	Mixed
Age (secondary)	Above 14	Level of focus	High
Gender (secondary)	All genders	Location	Hill or mountain (ski resort)
Education (secondary)	CSFC certification	Motivation	Improving, winning

Demographics

The age group of ski racers that this thesis project will focus on are the U12 and U14 groups (ages 10-14). They are all genders. Children in this age group are going through puberty, which causes growth spurts and changes in body composition. They are beginning to build muscle, grow in height, and gain weight, which makes it difficult to continue to learn skills that require excellent balance.

User Behaviour

The frequency of participation indicates that the athletes are committed to the sport. Depending on the athlete's distance from a ski resort, this can be a weekday, weekend, or evening activity. The average duration of a training day is between five and seven hours, and can happen between two and six days a week.

Motivation to continue training and racing comes from having fun, improving skills and improving racing results.

Young ski racers lead an active lifestyle, which is reflected in the number of other sports in which they often participate. These activities include gymnastics, athletics, hockey, soccer, lacrosse, swimming, baseball/softball, ice skating, basketball, skateboarding, mountain biking, trampoline and others. It is important that athletes continue to be physically activity all year in order to maintain fitness levels.

Interestingly, there are no on snow devices to help alpine athletes train.

Persona

Name	Taylor Smith
Age	12
First time skiing	Age 3
First race program	Age 6
Education	Grade 7
Location	Collingwood, ON
Main sport	Ski racing
Frequency	Season dependent - Fall ski camps - Winter break training - Friday to Sunday training from Jan. to mid-Mar. - Occasionally night skiing
Duration	5 to 7 hours per training day 2 to 4 hours of gate training/day
Social	Trains individually along with other racers that share the same coach
Other pursuits	- Basketball (school team) - Mountain biking

Figure 5: Lacie Greenwald, 12-Year-Old Hobe Sound Ski Champion (Laciegreenwald.com, 2014).

Profile

Taylor Smith is a 12-year-old from Collingwood, Ontario. They are in grade seven. Taylor's main sport is ski racing. They have been skiing since they were three and racing since they were six. They starting to ski as it was a regular family activity. Taylor fell in love with the sport and hopes to be able to race at the Olympics one day.

Taylor is working on balance, strength, and getting used to their growing body with help from their coach.

User behaviour

Taylor's first training camp of the season with their team is in November. The team members enjoy each other's company while on the ski lifts. While skiing, they concentrate on doing what they have been asked to do by their coach. After a day on the hill, they gather for dryland training, which may involve running, a game of volleyball, or calisthenics. After dryland and dinner, the team gathers to tune their skis and prepare their equipment for the next day. They take very good care of their equipment, as they understand how important it is to their success. After the fall training camp, Taylor looks forward to starting regular season training and racing over the school winter break. They are motivated to train hard in order improve their race results this season.

Conclusions

Taylor is a representation of the average competitive Canadian U14 ski racer. Even at this young age, Taylor is committed to the sport. A serious racer like Taylor is motivated and is likely to be eager to use new techniques and products that will improve their performance.

User Observation Report

Objective

Needs Statement

This thesis is focused on developing alpine ski racers between the ages of 10 and 14. Current on-hill skill development is achieved through verbal communication, which can be misunderstood. Skiers are also trained with drills, which may be completed incorrectly. Non-active training is carried out through observation, which is done with the racer standing still, and video review, which happens at the end of the day when the racer is off-snow. There is currently no training device that improves a racer's skills while they are skiing.

Description

This observation is to identify how coaches and athletes communicate. Questions that will be asked include what are the main forms of communication and how do athletes react to each form of communication.

Research Objectives

An observation of how coaches and athletes communicate is important. Athletes must understand what their coaches are trying to tell them in order to succeed. Communication goes beyond verbal exchange. It can include copying physical movements and non-verbal cues. The purpose of this observation is to understand how coaches and racers communicate with each other and attempt to identify barriers and where improvements can be made. This information will be collected through an observational study at a hockey practice.

Key Activities

As it is not winter, in-person observations on snow are not possible. However, this thesis focuses on communication. Therefore, it is important to observe the interaction between coaches and athletes and also ask each of them questions. As there is no ski training at this time of the year, warmups and drills will be observed at a hockey practice with children in the target age group.

Target Users

The primary users of this product are racers between the ages of 10 and 14. The secondary users are coaches.

User Environment

Observations will be made of the interactions between coaches and athletes at a hockey practice with children in the target age group.

Direct User Observation

A hockey team practice was observed and documented. Different types of communication were observed between coaches and athletes.

Chronology

Drill one.

5:54 – One of the coaches explains a drill. The team is collected at the boards. The coach explains the drill verbally while drawing pathways on the boards. The team is listening and quiet. Two players ask questions for clarification and the coach re-explains and tells them to watch a couple of other groups go before them in the drill so they can see what they are supposed to do.

5:55 – One of the coaches tells the team to collect the pucks on one side of the ice, puts two defensemen on the far blue line, and a goalie in the net.

5:56 – The two coaches and one player physically demonstrate how to do the drill. When they are done the demonstration, one coach says “Remember: fast passes, accurate passes.”

5:57 – One of the coaches whistles to start the drill. The first group of three starts. The same coach blows his whistle to tell the next group to start. There are three groups in total. As the groups are skating back in line one of the coaches is giving verbal feedback.

5:59 – Each coach adds themselves to a group and starts to do the drill with the team (two kids, one coach). One of the kids falls down and a coach checks on him. He verbally asks if he is okay and if he is good to keep going while skating towards him.

6:01 – One of the coaches blows the whistle three times and calls the team back to the boards to

explain the next drill. Throughout this drill, improvements were seen in the players' skills.

Drill two.

6:03 – While the forwards, defensemen, and a goalie are on one side of the ice doing the new drill with one coach, the other coach is on the other side of the ice with the second goalie giving him one-on-one instruction. He explains that the goalie is going to start by looking in the opposite direction of the puck and then the coach is going to slap his stick on the ice. Next the goalie has to move into position, and the coach is going to shoot. The coach does this through verbal instruction while moving his body the way the goalie will be moving.

6:05 – The coach stops shooting pucks at the goalie and skates towards him. He tells him what he has been doing right and what he needs to work on. The coach then moves into the net and shows the goalie how he should position himself while re-explaining verbally. He then moves out of the net and breaks down the movements slowly with the goalie doing each one. The coach

then starts to shoot pucks again. There is a visible improvement in the players positioning and response time the more he does the drill.

Organizing the Data

Key activity one.

Verbal instruction was the most prominent communication method. The coaches would verbally explain the drill while drawing on the board. The coach would also explain while demonstrating each drill, and while the team was completing the drill.

Key activity two.

Visual communication was used during verbal communication. One of the coaches would draw each drill on the board while explaining it verbally. Then he would physically demonstrate the drill while verbalizing the steps so the team could see what he was explaining in real time. The team also learned through visual communication by watching their peers.

Key activity three.

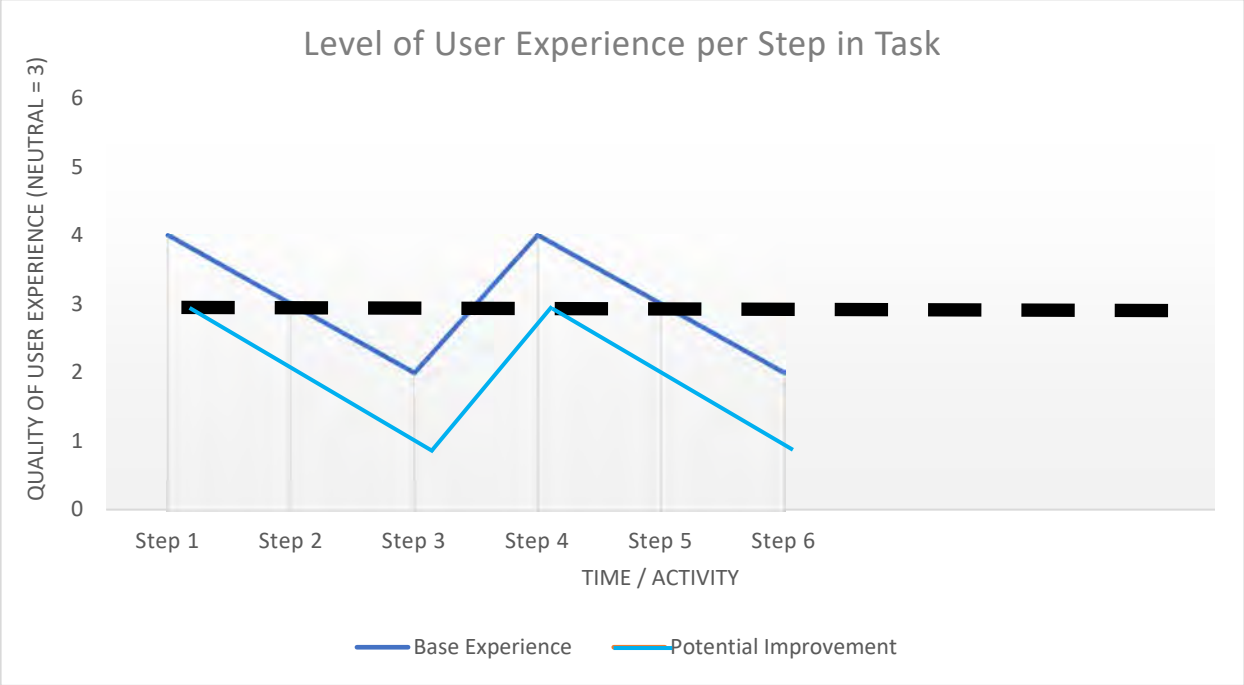
Kinetic communication was mostly seen through the repetition of drills. It was also achieved by the coaches physically demonstrating the drill before the players completed the drill. There was, however, one big kinetic communication session when the coach and the goalie were working together one-on-one when the coach broke down each step of the goalie's exercise slowly. Very small movements were repeated slowly before putting them together into one motion.

User Experience

User Experience Map

Step #	Description	Gradient scale of understanding ease (1= easy, 5= difficult) 1	2	3	4	5
1	Coach explains drill verbally at boards				*	
2	Coach draws explanation on boards			*		
3	Coach gives physical demonstration		*			
4	Players start drill				*	

5	Coach yells out key words for reminders			*		
6	Players get better at drill		*			



Potential User Experience Improvement Chart

Step #	Description	Gradient scale of understanding ease (1= easy, 5= difficult) 1	2	3	4	5
1	Coach explains drill verbally at boards			*		
2	Coach draws explanation on boards		*			
3	Coach gives physical demonstration	*				
4	Players start drill			*		
5	Coach yells out key words for reminders		*			
6	Players get better at drill	*				

This observation shows that the players' understanding improves as each drill progresses. When the coach is verbally explaining and drawing on the board there is some understanding, however there is still some difficulty. As the drill progresses, the understanding improves. As the players are still learning, their understanding can never be at 'level 1'. Ideally, the players' first level of understanding should be neutral, and improve from there.

Observation Analysis

The observation provided insight from an outsider's perspective. Communication patterns were studied and documented. The observation reaffirms the information collected in the

interviews. Throughout each drill process, the three previously discussed communication methods were all observed. Verbal communication was the most common method, and it was often used in conjunction with visual communication. Kinetic communication was the most interesting to observe because it provided the clearest explanation for each drill. The information collected in this observation will be useful when designing the solution for this thesis problem.

iii Product Research

Benchmarking & Benefit and Features

Methods

This thesis focuses on communication between racers and coaches while training. In order to design a solution for the posed thesis problem, current communication and coaching products have been benchmarked. This was done by searching key words, such as "ski communication," "mountain biking communication," and "F1 racing communication." Current products may have features and benefits that should be met by the thesis solution.

Six products have been found and their benefits and features have been noted. The major similarity in each product is that they all either help with communication between people or communicate with users themselves. This thesis can draw inspiration from the different ways these products use communication.

Evidence

	Product Image	Description (name and specs)
1	 https://www.motorolasolutions.com/en_xp/products/two-way-radios-story/analog-business-radios/discontinued/gp328.html#tabproductinfo	Motorola GP328 Practical two-way radio 8 to 10 hours of battery life Dimensions: 137 mm x 57.5 mm x 37.5 mm Weight: 420gms 16 channels Cost: unsure (~$100)

2	 https://bonx.co/en/how-to/snow/	Bonx Dual microphone Weight: 15g Size (without earloop): 44mm x 18mm x 32mm Lithium polymer battery Playtime using Bonx apps: 7 hrs (expected) MicroUSB charging Cost: $179.95CAD
3	 https://www.racingradios.com/collections/complete-systems/products/long-track-mobile-cm300d	Digital Long Track Mobile System – CM300D (The box) 99 channel capacity Dimensions: 44 x 169 x 134 mm Weight: 2.9 lbs (1.3 kg) Operating temperature: -30°C / +60°C Cost (whole system): $1695
4	 https://www.sena.com/product/expand	Sena Expand Talk time: 10 hours Operating temperature: -10˚C to 55˚C Dimensions: 145 mm x 115 mm x 78 mm Weight: 91 g Working distance: up to 900 meters (open terrain) Charging time: 2.5 hrs Cost: $169
5	 **Figure 41- Rossignol & PIO** https://www.rossignol.com/us/alpine-piq	Rossignol & PIQ Wearable Ski Sport Tracker Weight: 45.4g Dimensions: 4.4 x 3.9 x 0.5 cm Batteries: 1 Lithium Polymer battery Battery life: ~3 hours App use required Cost: ~$250CAD

6	 https://getcarv.com/device	Carv digital ski coach 96 pressure sensors <2mm thick & 296g per foot 9-axis 3d motion battery lasts for 3 days, uses low energy blue tooth fully waterproof design including all weather connectors App use required Cost: $279 USD

Conclusion

These six products either enable communication or communicate in some way. Products one to four are used for verbal communication, and products five and six use kinetic information to communicate visually on a phone application. This information gives insight into communication and skiing products that are currently on the market. It also reveals that there are gaps in the market that the designer can use to their advantage.

Benchmarking II

Method

Two scatter plots will be completed that compare different features of the benchmarked products. One will compare how technology-intensive the products are versus the price. These features are being compared because more complex technology often makes a product more expensive. The other will compare the battery life of the products versus the weight and size. These features are being compared because often a product with a longer battery life is heavier, as the battery is larger.

This scatter plot shows how the products align when being compared by price and how technology intensive they are. The Motorola GP328 is the most commonly used communication device at ski resorts because it is the least expensive and the least technologically intensive. The most technologically intensive and the second most expensive product is the Carv footbeds. They have 96 pressure sensors, and they communicate with the skier through a phone application. Carv gives skiers the opportunity to improve without a coach.

This scatter plot shows how the products align when being compared by battery life and size. The Motorola GP328 has a battery life of eight to ten hours and is one of the heavier products. Bonx is significantly lighter than the Motorola GP328, and the battery can last for seven hours.

When comparing all four features, it can be seen that the ideal product in this family of products is the Sena Expand. This product is small, has a good battery life, is not too expensive, and not too technologically intensive. These scatter plots reveal design opportunities. The products shown are either verbal communication aids or training aids. There are opportunities to combine the communication aspect with the sensory responses in the training aids.

Benchmarking III

Method

To determine the main benefits and features of the benchmarked products, word searches were completed and on the websites where the products' information was found. This information will reveal the most popular features and benefits in this communication products category.

Key Benefits

Key benefits of comparable products	
Lightweight	2
Communication	6
Waterproof	4
Voice activated	2

Key Features

Key Features of comparable products	
Lithium polymer battery	3
Waterproof	4
Voice activated	2

Discussion

This thesis is concerned with communication between ski racers and coaches. The feature comparison can help when informing the thesis product's design. It shows that there are different ways people can verbally communicate. It also shows that there are different solutions to the communication barrier beyond radios, walkie-talkies, and blue tooth, such as sensors placed on the body that transmit information. This is important information to have as it will help inform design decisions as the product progresses.

The scatter plots will also help to inform the final design. The four features that were graphed are all important to take into consideration when designing the thesis product. As the primary user is a child between the ages of 10 and 14, the product should be easy to use, lightweight, and last a long time. Price is also important to consider because these children are growing and therefore parents have to buy new equipment almost every year.

Key benefits and features previously listed will also inform the final design. As this product will be used outdoors in several different types of weather conditions it should be waterproof. It should also be lightweight, so the user is not impeded. While voice activation would be a useful addition, it is not necessary for the product's success. Having looked at other products in this category, it is clear that there are opportunities to design a new product that can better help athletes and coaches communicate with each other.

iv Needs Analysis

Needs Statement 1/ Data

What the product does

Aids in the development of an alpine athlete's skills.

360 initial inquiry

Who are your target market group?	Coaches and athletes
What does it do?	Aids in development of skills
Where will it be done?	Outdoors on ski hill/mountain
When is it done/used/needed?	During the day
Why is it needed?	To develop skills, build confidence

Why would someone buy this product?

- To help when training young alpine ski racers
- To explain core concepts more accurately, allowing athletes to learn and improve faster.

2 Linking Benefits to Human Needs

Products with similar benefits were determined, and promotional media for them gathered.
A more in-depth look at the benefits listed in the promotional literature was carried out.
These benefits were related to Human Needs using:

1) Hierarchy of Human Needs *(Mazlow)* and
2) Fundamental Human Needs *(Max-Neef)*

Thesis Topic

How may we aid in the development of ski racers in a competitive environment between the ages of 10 and 14?

Benefits that bracket topic

1. Helps improve balance
2. Help build strength

Table: Benefits and Corresponding Fundamental Human Needs
Skill development in alpine ski athletes

	Benefit	***Possible Corresponding Fundamental Human Needs (FHN)***	***Relationship between Benefits and FHN***
1	Comfort	Control, security, self-esteem (mastery)	strong
2	Style	Esteem, belonging, aesthetically pleasing	weak
3	Efficiency	Accomplishment, autonomy, self-esteem	strong
4	Ease	Accomplishment, autonomy, protection, security, control, self-esteem (mastery)	strong
5	Fun	Leisure (excitement), Participation, Belonging (shared fun)	strong

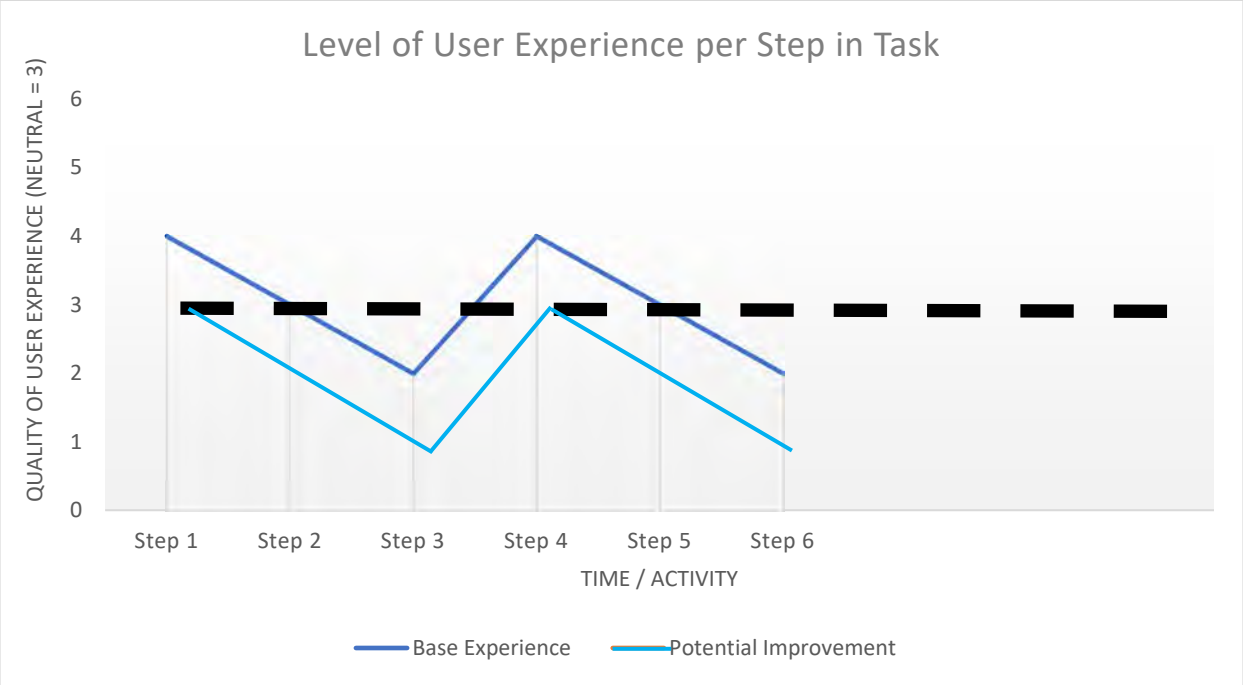
Comfort is important in this context, as it increases the athlete's confidence on the hill. It is also important that the product be comfortable to use. Learning how to control the body by improving balance and strength will increase the athlete's comfort. Also, improving balance and strength will improve the athlete's self-esteem.
Style is an important expression of individuality. As this device will be used by multiple people in order to improve skills, it does not need to be individualized stylistically for each athlete. However, the style of skiing that will be the result of using this product (good technique) will build a sense of belonging and self-esteem.
Efficiency in the use of this product will be important. It should help athletes learn new skills and improve at an accelerated rate. Improving technique will build the athletes' self-esteem, as they will become better skiers, and faster skiers, making them more competitive. Also, the user, an athlete, will still have some autonomy/control over the product in order to stay safe.
Ease is in many ways related to efficiency in terms of fundamental human needs such as **control and autonomy**. With ease of use, this product can be helpful and build self-confidence as the athletes acquire and improve skills. The autonomy and control the athlete will have after using the product will also improve confidence and lower the risk of injury.

Fun in this context is about increasing an athlete's skills. With improved skills, the athlete will be able to ski on harder terrain with confidence and have more enjoyment of the sport. Also, ski racers enjoy the feeling of speed, and they will be able to increase their speed with better skills.

Statement of Need

Developing balance and strength in ski racers between the age of 10 and 14 is an important way to build their skills and make them better athletes. This will also build their self-confidence.
Helping young ski racers build their skills will encourage them to continue racing. This is also important for the continued growth of the sport.
A device that helps with the development of young ski racers will have many benefits.

Activity Experience Graph, Data



Step	Current Steps	Potential Improvements
1	Coach A explains drill verbally on hill.	Coach A explains drill verbally on hill. This first step is the same as it is the best way to start.
2	Coach B gives physical demonstration (or has a reliable racer demonstrate). Coach B stops in the middle of the hill to watch each racer perform drill.	Coach A and B give physical demonstration of drill. This allows racers to visualize what their bodies are supposed to look like. Both coaches stop at bottom of hill to watch each racer perform drill.

3	Racers go down the hill one by one doing drill (spaced out by coach A).	Racers go down hill two at a time (if there is no space one at a time). Racers are spaced out by coaches sending visual or radio signal.
4	Racers stop at coach B, receives verbal feedback. Simultaneously coach A points out corrections or good movements to the racers standing at the top of the hill to give a visual for them to learn from.	As each racer is skiing, coach A or B is able to give feedback while racer is in motion. This allows the racer to make immediate corrections to their movements.
5	Racer continues down the hill trying to implement corrections coach B just gave.	Racers can continue to rotate, not having to stop at the coaches for feedback, which will allow racers to get more runs in and more time on snow.
6	Racers' skills improve through repetition.	Racers' skills improve through repetition and visual, verbal, and kinetic reminders from coaches.

v CAD Models

All photos regarding SolidWorks model development and rendering can be found in section 4.7 and 5.3.

vi Hard Model Photographs

All photos regarding the building process and final thesis model can be found in section 4.8 and 5.4.

vii Technical Drawings

All technical drawings can be found in section 5.5.

viii Manufacturing Cost Report

The breakdown of the manufacturing cost can be found in section 5.2.3.

ix Sustainability Report

Ski racing is an extreme sport. Materials used in the objects surrounding the sport must be durable. This is because they must last as long as possible, be usable in all weather conditions, and function through the vibrations from the snow. The materials that will be used for this thesis solution must be durable and long lasting, but also comfortable.

To determine the best possible materials for the thesis solution, the benchmarked products will be examined along with the Cradle to Cradle website and other informative articles.

Literature review

The textile industry sees socio-economic, ecological, and environmental advantages that can be brought about by recycling garments and textiles and moving towards a circular economy (Leal Filho et al., 2019). A circular economy can reduce production from virgin materials and therefore reduce water, energy, and chemical consumption (Leal Filho et al., 2019). However, _ et al writes, "…textile recycling is… facing a number of challenges… limited practical technologies for recycling various types of fibres, technical problems related to the complexity of clothes, and immature markets." (Leal Filho et al., 2019). The market is not large enough to take the amount of material that comprehensive recycling would make. Additionally, cotton and crude oil are still more economic that recycling textiles (Leal Filho et al., 2019).

FIS (Fédération Internationale de Ski – Internation Ski Federation) also has a sustainability initiative. FIS says "that skiing must take into account the preservation of nature and the environment" (FIS, 2018). FIS recognizes that ski events and the facilities required for them must be compatible with the local environment (FIS, 2018). They also understand that their initiatives cannot be adopted identically throughout the world, and that different places require different cultural, social, and environmental solutions (FIS, 2018).

Benchmarking – Materials and Manufacturing

Current Products

Current products often use rigid plastic, such as the Motorola GP328 and the CM300D of the Digital Long Track Mobile System. The cases of these devises appear to be injection molded. Bonx is made of a soft rubber so that it is comfortable to wear throughout the day. While there is no information on the Rossignol & PIQ Wearable Ski Sport Tracker, Sena Expand, or Carv Digital Ski Coach, it can be assumed that these devices are all made of plastics and fabrics.

New Materials and Technologies

The Cradle to Cradle Certified Registry was explored to find sustainable materials for the design solution. Threads, fabrics, and plastics were examined. Following is a list of materials and their Cradle to Cradle certification level.

Threads and Fabrics

- Natura – Gold certification (Cradle to Cradle, n.d.)
- Amann – Gold certification (Cradle to Cradle, n.d.)
- Pratibha – Gold certification (Cradle to Cradle, n.d.)
- Inogema – Gold certification (Cradle to Cradle, n.d.)

Plastics

- Sea2sea Upsea Plast – Gold (Cradle to Cradle, n.d.)
- Nature Works Ingeo – Bronze (Cradle to Cradle, n.d.)
- SK Chemicals Ecozen and Skygreen – Bronze (Cradle to Cradle, n.d.)
- Eastman Chemical Company Eastman Provista – Bronze (Cradle to Cradle, n.d.)

Benchmarking - Sustainability

Sustainability is an important factor to consider when designing a new product. Looking at the benchmarked products' companies' sustainability initiatives will aid in this process.

Motorola considers their products' entire lifecycle. Some examples of their initiatives include using recycled plastic where possible, and their chargers use less energy than U.S Environmental Protection Agencies ENERGY STAR standard (Motorola Mobility LLC, n.d.). They also give information to their customers on how to dispose of their products properly (Motorola Mobility LLC, n.d.).

Rossignol joined Global Compact in 2015 (Groupe Rossignol, 2019). The company only uses synthetic fur, 64% of the down they use is synthetic, and the rest of the down, feathers, and leather are food-industry by-products (Groupe Rossignol, 2019). Several clothing items they produce use polyester made from recycled materials, and their ski helmets are now 100% recyclable (Groupe Rossignol, 2019). Additionally, Rossignol will collect equipment at the end of its life to dispose of each part properly (this includes skis, snowboards, poles, and ski boots) (Groupe Rossignol, 2019). Only a few initiatives have been mentioned as this company creates a wide range of products.

Sustainability – Safety, Health, & Environment

In the area of sportswear, or products used by athletes, the choice of material that is used is important. Anything a racer puts on their body must not hinder any movement for safety. It also must not cause injury, should the athlete fall, or distract the athlete from their training. Another aspect the product solution must consider is durability and the wear and tear the racers will put on the product. Ski racers fall, hit gates at high speeds, and absorb vibrations from the terrain, so the product solution must be able to withstand these conditions. It can be projected that the product solution will be made of different types of plastics and fabrics. The material and manufacturing options will follow the patterns of current ski protective wear.

Safety and Health

The most important aspect to consider when designing the product solution is the safety of the athlete. Young racers are more likely to sustain an overuse injury due to growth spurts (Steidl-Müller, Hildebrandt, E, Fink, & Raschner, 2018). The primary user group, racers age 10 to 14, are in the middle of puberty and therefore their bodies are constantly changing. It is important to recognize this and design a solution that will help them continue to develop their skills during this time of their lives. When racers understand how to properly move their bodies, good habits are created, and therefore they will be able to continue their development seamlessly during and after puberty. Knowing the proper movements will also likely lower injury rates, as other parts of the body will not be compensating.

The environment must also be taken into account when considering the health and safety of these athletes. As training and racing takes place in cold temperatures, skiers wear many layers. Cold weather affects the nervous system and physical and cognitive performance, which decreases postural control and increases injury risk (Raschner, Hildebrandt, Mohr, & Müller, 2017). The product solution will add a garment layer in some areas, therefore helping to keep parts of the body warm.

Environment

Most often, ski gear and equipment is donated, passed down, or sold when a racer is done with it. As gear is expensive, it is very common for a younger racer to use an older racer's old

equipment. Many ski equipment stores will take used equipment and donate them to underprivileged places or send them off to be recycled and disposed of properly.

The product solution should use sustainable materials where possible. This can be achieved by using recycled materials, such as plastics and textiles, for the main body of the product. As there will be batteries and other technological elements involved, it is important to consider the end of the products life as well. It will be important to dispose of all of the parts properly as to not cause more environmental damage.

Sustainability

The final design solution for this thesis is a human centered training device for ski racing. The final design will have sustainable aspects for user and environmental health and safety. The upper body wearable and calf sleeves will use Pratibha Syntax fabrics. This company is vertically integrated, fair-trade certified, and makes sustainable textiles, including fabrics in the active-wear category (Pratibha Syntex, n.d.). They primarily use organic fabric, recycled polyester, viscose, and hemp (Pratibha Syntex, n.d.). An option for the threading is Natura thread. This thread is made from 100% cellulose fibers, organic cotton, or a biodegradable polymer (Johann Muller AG, n.d.). Their materials are also dyed with a Cradle to Cradle assessed dye chemicals (Johann Muller AG, n.d.). The plastic that will be used for the final product is Ingeo by NatureWorks (NatureWorks, n.d.). This is a plant based plastic, however the company is, "…assessing new technology to skip plants and use microorganisms to directly convert greenhouse gases…" into plastic (NatureWorks, n.d.).

x Topic Approval Form

Humber Institute of Technology & Advanced Learning — School of Applied Technology
Bachelor of Applied Technology – Industrial Design — **Fall 2019**
IDSN 4002 Senior Level Thesis 1
Catherine Chong, Dennis Kappen, Sandro Zaccolo

THESIS TOPIC APPROVAL

STUDENT NAME

Lindsey Moscoe

TOPIC TITLE
How may we aid in the development of ski racers in a competitive environment between the ages of 10 and 14?

TOPIC DESCRIPTIVE SUMMARY

This thesis proposal investigates both the skills development and safety of young alpine ski racers. Current on-hill skill development is done through verbal communication, which can be misunderstood, drills, which may be completed incorrectly, observation, which is done with the racer standing still, and video review, which is done at the end of the day when the racer is off-snow. There is currently no training device that improves a racer's skills while they are skiing. This thesis proposes an in-depth study of the user, how they grow, the skills they must master, and the functionality of the human body, through data collection, observational studies, interviews, and surveys. A detailed analysis of the evaluation process will be done with the goal of minimizing the negative experiences and maximizing the positive experiences of alpine ski racers. A one-to-one scale ergonomic model will be built in order to evaluate the ergonomics and human factors design needed to establish a full-bodied human interaction design solution. Results from the specific studies will be used to design the next generation ski race skill training devices. Designing a skills training device from ethnographic considerations will help improve the human interaction design aspects of ski racing.

Student Signature(s) Lindsey Moscoe

Date Sept. 30/19

Instructor Signatures

Date

xi Advisor Meetings & Agreement Forms

Advisor: Andrew Moscoe
Information letter:

2019-20 Industrial Design Thesis Project HUMBER

INFORMATION LETTER
Title: Developing ski racers between the ages of 10 and 14.

Investigator: Lindsey Moscoe

Sponsor: Humber College
Introduction

My name is Lindsey Moscoe, I am an industrial design student at Humber College. I am requestin your participation in a research study on developing skills in young ski racers. Major skills include balance, strength, and separation. The results will contribute to my senior project/thesis.

Purpose of the study

This study is being conducted to be an aid in the designing of a product that will help to develop skills in ski racers between the ages of 10 and 14. With your help, I plan to examine current training barriers these athletes face on a regular basis. This study is primarily based on understanding ergonomics, human interaction design activities, and user experience aspects of the research area.

Procedures

If you volunteer to participate in this study your answers to any questions will be documented. Your activities in interacting with athletes/coaches and training devices may also be observed and documented. They will be documented by photo/video.

Confidentiality

Every effort will be made to ensure confidentiality of any identifying information that is obtained during the study. In the case of being recorded visually, your face will be masked /blurred or hidden. The information and documentations (photographs) gathered are all subject to being used in the final presentation of the study.

Participation and Withdrawal

Your participation in this study is completely voluntary and you may interrupt or end the study and the session at any time without giving a reason or fear of being penalized.

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.

2019-20 Industrial Design Thesis Project HUMBER

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

Andrew Moscoe
Name of Participant (please print)

Andrew Moscoe — Oct. 4, 2019
Signature of Participant — Date

Guardian Name : _____

Guardian Signature : _____

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, please contact me at Ph: (416) 904 3836, email: Lindsey.moscoe@gmail.com

My supervisors are:
Prof. Catherine Chong, catherine.chong@humber.ca, 416 675 6622 xt. 4672
or Prof. Dennis L. Kappen, dennis.kappen@humber.ca, 416 675 6622 xt 4832,

Informed consent form:

2019-20 Industrial Design Thesis Project

HUMBER

Informed Consent Form

Research Study Topic : *Developing ski racers between the ages of 10 and 14.*
Investigator : Lindsey Moscoe
Course : iDSN 4002/iDSN 4502

I, Andrew Moscoe, have carefully read the Information Letter for the project. 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 **Lindsey Moscoe** via email **lindsey.moscoe@gmail.com** at any time during the project. I understand that this course has been approved by the Humber Research Ethics Board.

- ☑ I hereby give consent to have my voice recorded
- ☑ I hereby give consent to have photographs taken with the proviso that my identity will be blurred in reports and publications
- ☑ I hereby give consent to have videos taken 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 of data with privacy and confidentiality maintained in the Humber Digital Library which is an Open Access platform	☑	☐
Review	I give consent for review by the Professor	☑	☐

Withdrawal:

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

Privacy:
All data gathered is stored anonymously and kept confidential. Only the researcher Ms. Lindsey Moscoe, Prof. Catherine Chong, and Prof. Dennis L. Kappen 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.

My signature below verifies that 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.

Participant Name : Andrew Moscoe
Signature : Andrew Moscoe
Guardian Name : _____
Guardian Signature : _____

2019-20 Industrial Design Thesis Project

HUMBER

Verification of having read the informed consent form:

☑ I have read the informed consent letter

I, Andrew Moscoe *(First Name, Last Name, Signature)*, have read this document and give consent to the use of the data from questionnaires and interviews in research reports, publications (if any) and presentations with the proviso that my identity will not be disclosed.

Participants Name : Andrew Moscoe
Signature : Andrew Moscoe
Guardian Name : _____
Guardian Signature : _____

Humber Research Ethics Board

This course has been approved by the Humber Research Ethics Board.

If you have any questions about your rights as a research participant, please contact Dr. Darren Lawless, REB Chair, 416-675-6622 ext. 3226, darren.lawless@humber.ca.

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, please contact me at Ph: (416) 904 - 3836, email: lindsey.moscoe@gmail.com.

My supervisors are:

Prof. Catherine Chong, catherine.chong@humber.ca, 416 675 6622 xt. 4672

Or Prof. Dennis L. Kappen, dennis.kappen@humber.ca, 416 675 6622 xt 4832,

xii Other Supportive Raw Data

No relevant supportive raw data is included in this section.

xiii Topic Specific Data, Papers, Publications

PANEL ON RESEARCH ETHICS
Navigating the ethics of human research

TCPS 2: CORE

Certificate of Completion

This document certifies that

Lindsey Moscoe

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

Date of Issue: **3 September, 2019**