Performance Apparel for Recreational Skate Skiing Males Aged 50 and Over

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Introduction

Skate skiing is a fast, rigorous, and highly aerobic winter sport. Also known as cross-country skating or Nordic skate skiing, it has grown in popularity since its inception in the 1970's as an alternative form of classic cross-country skiing (Matt, 2016).

Skate skiing differs from classic cross-country in many ways. The equipment is specific to the sport as the skis are shorter and poles are longer than those used in classic cross-country. The boots tend to be more supportive in the ankle and bindings allow for the ski to be lifted from the snow. (Cross country skiing, n.d.)

The most significant differences in skate skiing versus classic cross-country skiing are in the movement techniques involved. In skate skiing, the movements are much more lateral than in classic cross-country skiing. The skier pushes off the side of one ski then the other, shifting the weight forward from side to side and gliding, similar to ice or inline skating. Instead of in-track and in-line leg and arm motions, most skate skiers use a combination of V-shaped strides such as V1, V2, and V2 Alternate, to move through various levels of slope. (Matt, 2016)

History of Skate Skiing

In the 1970s some Scandinavian cross-country ski racers adopted what they called a marathon skate technique for parts of their races. It involved keeping one ski in the track and using the other in a lateral skating-style motion to get through difficult parts of the track. More and more competitors adopted the technique because it was so successful. (Bengtsson, n.d.)

The skyrocketing popularity of the technique in the 1980s is largely attributed to American cross-country champion Bill Koch (Fig. 1). He witnessed marathon skating while at a race in Sweden in 1980 and quickly adapted it into his program. He then used the technique to win the 1982 FIS Cross-country World Cup. (Halloran, n.d.)

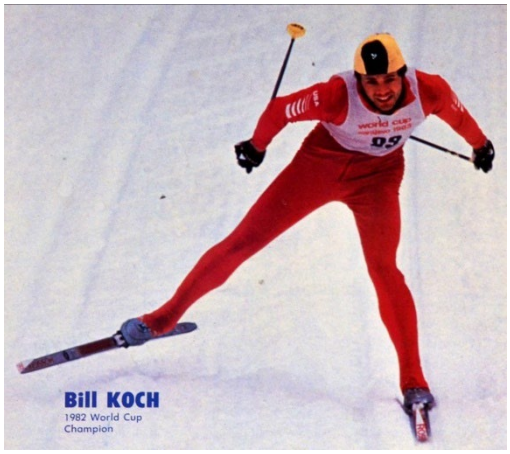


Figure 1 - Bill Koch Marathon Skating (French, 2013)

The governing body in Norway did not think the technique was good for the sport and began to make efforts to ban its use in racing. The athletes were not enthused about eliminating the skating technique, and by 1985, Nordic/cross-country skiing was split into two distinct categories. The traditional form would be called “classic” and any form incorporating

non-traditional techniques like skating would be called “freestyle.” Freestyle cross-country eventually came to be known as skate skiing. (Halloran, n.d.)

Athlete and Required Skills

This project is focusing on male recreational skate skiers, age 50 and over. These are fitness-conscious athletes who do some sort of physical activity at least three times per week. They also have the means and motivation to use better than average technical apparel for their sports activities. Much of this demographic are early adopters of new technologies and they desire the best apparel for any activities they perform.

The reason for the focus on these athletes, and in particular this age group, is because they are a population who grew up being more physically active than their parents and have continued to prioritize staying active longer in life. One survey in 2017 showed that 56% of people over 40 admitted to doing some sort of physical activity at least once a week (AARP, 2017). Another aspect to consider is the fact that the physiological ability to adapt to temperature changes diminishes with age (Kemp et al, 2014).

Skate skiing requires endurance, strength, and balance to master the techniques involved (Clarke,2021). These athletes build up muscles they may not often use, particularly in the outer thighs (Clarke,2021). They also must be able to endure an aerobic workout lasting anywhere from 30 minutes to a few hours at a time, with short breaks.

Sport Environment

Skate Skiing is done in winter on outdoor groomed snow paths. The paths are often groomed alongside classic cross-country ski tracks and they can wind through wooded areas or open parks or fields (Fig. 2). The paths usually have various degrees of incline, decline, and flat terrain and there are no regulations on their characteristics.

Figure 2 - A Groomed Skate Ski Path (Pokorny, 2018)

The best temperature range for classic and skate skiing is between 20 and 30 degrees Fahrenheit (Fulton, 2022). The sport is usually done in low humidity and conditions can be windy or calm, snowing, cloudy, or clear and sunny.

Sport Equipment – Skate vs Classic Cross-country

Even though skate skiing was derived from classic cross-country skiing, the equipment used is different to match the unique needs of the athlete. Skate skis may look similar to their classic counterparts, but they are actually quite different. Like classic skis, skate skis are fit based on the height and weight of the athlete, but skate skis tend to be approximately 10 cm shorter (Fig. 3). This is because with a v-shaped stride, you are more likely to hit the backs of the skis together if they are longer. They also need to be lighter, so the skier can totally lift the ski during strides and to provide a more solid edge they have no side cuts. Skate skis also tend to be less flexible and have less of a camber than classic cross-country skis. (How to choose, n.d.)

Because the skating techniques involve twisting forces, skate skiing boots offer more ankle support than classic cross-country boots. To help minimize forward and torsional flexing, skate ski boots also have stiffer soles. (How to choose, n.d.)

Skate skiing poles are longer than cross-country poles (Fig. 4). They should be 90% of the skier's height, reaching up to their mouth, as compared to classic cross-country poles, which are 83% of their height (Gear, n.d.). This allows better utilization of the major muscle groups of the upper body for propulsion (How to choose, n.d.).

Figure 3 - Skate Skis & Classic Skis (Cross-country skis for Grand Mesa, 2022)

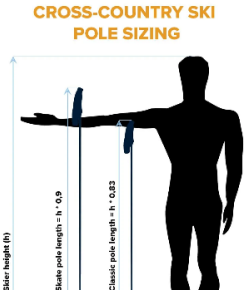


Figure 4 - Classic vs Skate Ski Pole Sizing (Gear, 2022)

Physiology of Skate Skiing

Both skate and classic forms of cross-country skiing are full-body, highly aerobic activities. While the physiological benefits of aerobic activities are well-known, the benefits of cross-country skiing throughout life, and continuing later in life, have been quantifiably proven in the last decade.

Researchers in Sweden and at Ball State in Indiana published a study in 2013 which they conducted on two groups of men aged 80-91 years. Both groups were thoroughly medically screened to ensure that each subject qualified to be in what the researchers agreed was a healthy status. In the Swedish group of 9 subjects, every man was a long-term cross-country skier who regularly participated in aerobic exercise (4-6 times/week) and endurance events throughout their adult lives. They had no longer than a 6-month period over the past 50 years without regular training. The 6 subjects of the nonendurance-trained group were American men in Indiana who did not exercise beyond daily activities. Daily physical activity of each subject was indirectly assessed using a pedometer throughout the day for 2 weeks. (Trappe et al., 2013)

Each subject completed a maximal cycling test in which values were recorded for maximal oxygen consumption (VO_{2max}), ventilation, heart rate, pulse-oximetry, respiratory exchange ratio (RER) and final workload achieved. Skeletal muscle biopsies were also taken on each subject to determine myocellular markers of oxidative metabolism. (Trappe et al., 2013)

As expected, the results showed that the lifelong cross-country skiers were more fit, but the magnitude of the differences in the two groups was astounding. The myocellular testing

showed that the long-term endurance athletes had approximately twice the aerobic capacity of the other group. Their VO_{2max} values, an indicator of endurance, were significantly different as well. According to the study's lead author, Scott Trappe, the observed VO_{2max} of the lifelong cross-country skiers was "the highest recorded in humans in this age group, and comparable to nonendurance-trained men 40 years younger." Trappe goes on to conclude, "Since we are living longer, our research indicates that lifelong exercise enhances physical capacity, has powerful anti-aging effects, and emphasizes that exercise is medicine." (Ransford, 2013)

Biomechanics of Skate Skiing

The whole body is utilized to make the movements involved in skate skiing. The main movements are all about accelerating the body's center of mass over one ski by, utilizing the legs, pushing off the other (planted) ski at the same time as the athlete is pushing with one or both of their arms to transmit force down their planted pole(s), thus propelling them forward. The weight is transferred from ski to ski to propel them down the trail. Movement is achieved through a series of pushing, then gliding, then pushing, then gliding and so on. (Göpfert et al., 2016)

These movements are combined into distinct techniques to tackle the various terrain along the ski path (Fig. 5).

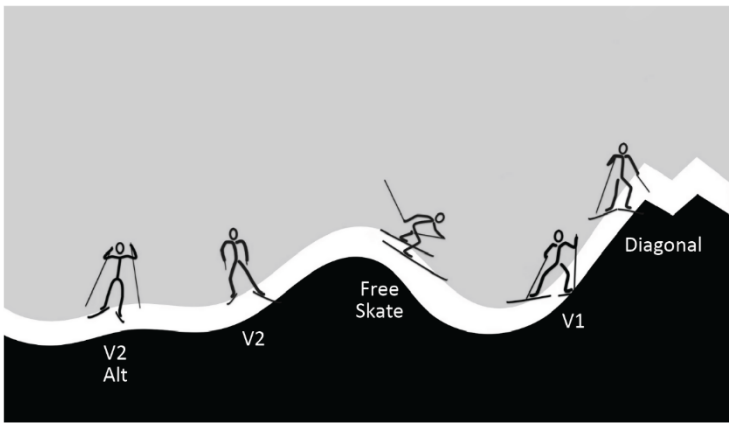


Figure 5 - The Five Main Skate Skiing Techniques and Where They Are Utilized (How cross-country ski techniques work, n.d.)

Beginner skate skiers find the sport challenging and they face a steep learning curve. According to the online Nordic Ski Lab, the initial difficulties in learning to skate ski partially stem from the fact that "the mechanics of skate skiing are unique and unrelated to other

sports, including ice skating." They also state that the keys to successfully mastering the sport are to have properly fitting, high quality equipment, to learn the actual techniques, and to understand the mechanics of how your feet and your skis should work together. (Top tips for new skate skiers, n.d.)

1. V1 Technique

The V1 technique, also called Offset technique, is used to climb steeper hills. It is considered the easiest technique to learn but most difficult to master. (How cross-country ski techniques work, n.d.)

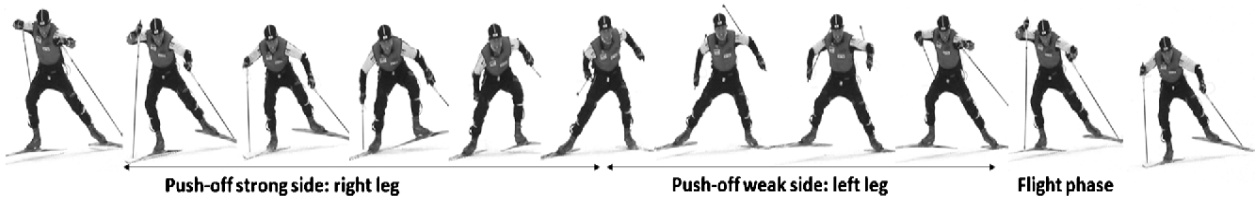


Figure 6 - Sequence of Actions for V1 (Stöggl, 2010)

To better understand the athlete actions involved, the United States Ski and Snowboard Association gives a detailed description of the V1 technique in their published "Cross-country Technique Fundamentals" (V1 summary, 2006, pp 2-3):

> "The V1 technique is described in terms of the hang arm. If it is the skier's left hand that is placed high and next to the head at the start of the poling motion, the hang side (also called poling side) is the left side. On the poling-side the entire upper body and poling-side leg push simultaneously down and over to transfer weight to the non-poling side. There is little to no time spent inactively gliding in the V1 technique. As soon as the skier's weight is shifted onto the non-

poling side the arms begin to swing back up and forward as the skier begins the push-skate back onto the poling side. When the skier transfers weight back to the poling side the poles and poling-side ski meet the snow simultaneously."

2. V2 Technique

The V2 technique, also called One Skate technique, is used on flat terrain and mild inclines. It is usually the first technique taught because it is the most versatile, but it feels the least natural. (How cross-country ski techniques work, n.d.)

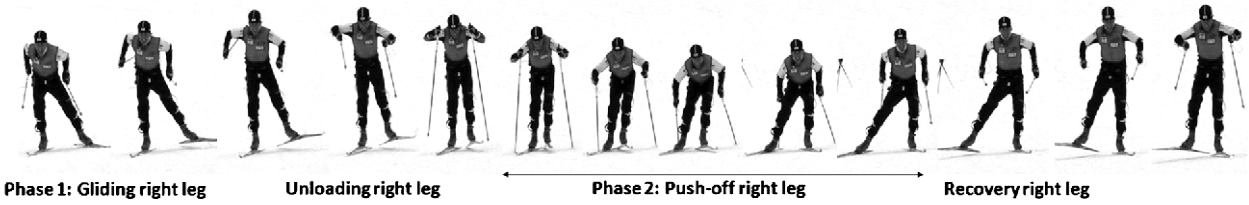


Figure 7 - Sequence of Actions for V2 (Stöggl, 2010)

To better understand the athlete actions involved, the United States Ski and Snowboard Association gives a detailed description of the V2 technique in their published "Cross-country Technique Fundamentals" (V2 summary, 2006, p2):

"In V2 the upper-body pushes in a double pole motion as the skier pushes simultaneously with the skating leg onto the gliding ski. The double pole and the skating push is complete as the gliding ski hits the snow and the skier's weight is transferred to that ski. While the skier is gliding the arms and whole-body return to the high position to initiate the double pole and skate-push that will take the skier back onto the initial ski. In this way the V2 technique is entirely

symmetrical, with the upper and lower body working together and in the same way on both sides."

3. V2 Alternate Technique

The V2 Alternate technique, also called Two Skate technique, is used for high speed on flat terrain and declines. It is a demanding technique but feels the most flowy when the skier gets going. (How cross-country ski techniques work, n.d.)

Figure 8 - Sequence of Actions for V2 Alternate (Stöggl, 2010)

The United States Ski and Snowboard Association gives a detailed description of the V2 Alternate technique in their published "Cross-country Technique Fundamentals" (V2 alt summary, 2006, pp 2-3):

"In V2 alternate, the method of propulsion on the poling-side is exactly the same as it is in V2. The upper-body and lower body compress together to transfer weight to the gliding ski. However, in V2 alternate the skier does not return to a high position on the gliding ski but stays in a relatively low position. The return to the poling-side is accomplished from this lower position with a skating push aided by the momentum of the arms swinging up, forward and back over to the

poling-side ski. The synchronization of this forward arm swing and skate push is integral to the effectiveness of this technique."

4. Free Skate Technique

The free skate technique, also called No Arm technique and sometimes V0, is used to glide down hills. The skier remains in a crouched position, shifting their weight from one ski to the other. Their poles are held backward horizontally, not engaging the ground. (How cross-country ski techniques work, n.d.)

5. Diagonal Skate Technique

This inefficient back and forth technique is only used by beginners, especially when climbing hills. It can be exhausting and is almost never used by experienced skate skiers. (How cross-country ski techniques work, n.d.)

Psychology of Skate Skiing

The psychological effects of skate skiing (and cross-country skiing in general) are overall positive, but these reports have only been anecdotal. The mental, cognitive, and psychological effects of this specific sport have not been studied. However, there have been a number of studies addressing the psychological effects of sport participation. In a 2019 systematic review of 23 studies of adults over 50, participation in sport showed an increase in subjective well-being, a higher level of life satisfaction, socialization benefits, and a resistance to the negative view of aging (Kim et al., 2019).

The benefits of getting out into nature for physical activities have also been studied. In a 2019 review of 51 studies looking at the therapeutic effects of nature-based recreational activities, reviewers found decreases in anxiety, decreases in depression, positive effects on cognition, and increases in the sense of well-being among subjects (Lackey et al., 2019).

Line Plan and Apparel Innovation Opportunities

Currently, there is no apparel specifically designed for the sport of skate skiing available in the United States. Skate skiers usually wear a hat, pants or tights and a jacket over an upper base-layer all designed for classic cross-country skiing. Since the sport requires different movements than the classic version, there exists a huge opportunity to create technical apparel specific to the movement needs of the skate skier.

This is a highly aerobic sport, done in a cold environment. As such, the need for the athlete to warm up and cool down can change dramatically and often. Various venting and other standard methods of incorporating thermoregulation into the garments are not adequate alone. More innovative solutions to allow heat release and increased ventilation are needed.

The potential for overheating is great, especially within this focused athlete population of aged 50 and over males. These athletes need to have a way of cooling off rapidly. Most of these athletes are not wearing bags and the "take the jacket off and tie it around the waist" method hinders leg movements and can fall off while out on a trail, resulting in loss of the garment. Taking off and stowing the beanie in the pants waistband is not ideal either. It would be beneficial to design into the garments a way to easily convert them to cool off quickly, without having to remove them and without hindering performance.

The plan is to design skate skiing pants, a skate skiing jacket, and a beanie which take into consideration all of the above.

Problem Question and Jobs to Be Done

The previously gathered information led to the problem question: How could we design an apparel system which supports movements specific to skate skiing while preventing overheating for recreational skiing males aged 50 and up?

Three jobs to be done by the apparel system were identified. The apparel must allow for movements needed for skate skiing. The apparel must provide significant heat and vapor release. The apparel must allow for user-controlled air flow when needed for rapid cooling off.

Market Space

Skate skiing is popular in many countries, especially across Europe and North America, so there is definitely a potential global market for skate skiing apparel. The number of skate skiers world-wide has never been directly determined, but it can be estimated using other published statistics.

In 2021, 4.5 million Americans participated in cross-country skiing (Outdoor Foundation, 2022). In 2019, it was published that the United States accounted for 32% of the global cross-country equipment market (ClickPress, 2019). Therefore, the number of skate skiers world-wide can be extrapolated by dividing the 2021 United States number by 0.32, which leads to a possible 13.5 million cross-country skiers globally.

If only 25% of those total cross-country skiers are skate skiers (a low estimate), using census data that 34% of the population are 50 and over and 49% of those are men (US Census, 2022), then there could be approximately half a million male skate skiers aged 50 and over globally.

Product Rules

Because this apparel will be designed for recreational use, there are no specific rules regarding their manufacture or function. However, one can argue that there are inherent expectations from the user for skate ski apparel. First and foremost, all apparel pieces should allow for all movements necessary for the sport of skate skiing. There would be an expectation of comfort, including ventilation for moisture management, while wearing the garments in the sport. The apparel would also be expected to protect the wearer from the environmental factors of cold temperatures and wind. Water repellence would also be expected, but waterproofness would not be required because temperatures while skate skiing are not conducive to rain.

Current Cross-country Ski Apparel - Parts, Function, and Materials

1. Cross-country Ski Pants (Fig. 9)
    a. Waistband – The function of the waistband is to hold the pants up and in place whether at rest or while doing activities. Waistbands for skate ski pants are usually 2-3 layers of material. Sometimes the main stretch is from the material itself, which is often a polyamide or polyester knit blended with a small percentage of elastane. Other times the stretch is from an embedded knitted rubber elastic band.
    b. Rear Panels – The upper rear panels of skate ski pants allow for increased movement ability. They are usually comprised of a stretch knit of a polyamide/elastane blend, a polyester/elastane blend, or a 100% polyester knit. These knits also allow for better breathability. Sometimes there is a gusset panel in the rear crotch as well.
    c. Rear Vent Panel – In the upper rear, just below the waistband, there are often either vent holes laser cut into the stretch woven fabric or a full panel of stretch mesh knit for ventilation.
    d. Front Panels – The upper front panels of skate ski pants function to block or resist wind penetration. They are often fabricated from 4-way stretch wovens of polyester/elastane, polyamide/elastane, or polyester/polyamide blends.
    e. Leg Cuffs – The leg cuffs of skate ski pants function to keep the pant legs down, over the boot and to keep out the cold air and snow. They are usually made from the same material as the front panels of the pants (see above). They either have an elasticized cuff, or they are open with either a polyamide/rubber elastic pull cord

with polyamide stop or a hook and loop strap. Many have a zipper for easier donning and doffing.

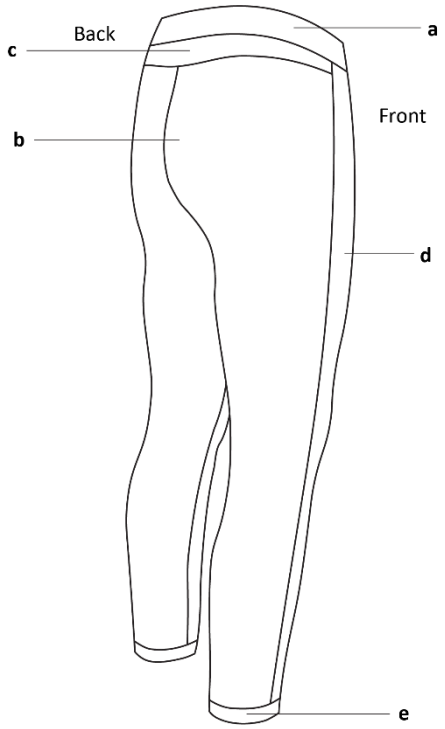


Figure 9 - Parts of a Pair of Cross-country Ski Pants

2. Cross-country Ski Jacket (Fig. 10)
    a. Collar – The collar extends partly up the neck to protect from the cool air. It is usually constructed of a multilayered softshell with an outer layer of polyester or polyamide woven softshell and inner fleece layer.
    b. Chest and Shoulder Panels – Wind resistance is their primary function. They are usually constructed of a multilayered softshell with an outer layer of polyester or polyamide woven softshell and inner fleece layer. Sometimes a durable water repellent (DWR) finish is applied to increase water resistance.

c. Front Zippered Pockets – The pockets are for storage or hand warming. The zippers are usually made of polyamide.

d. Main Back Panel – Stretch is their primary function. They are often constructed of a polyester or polyamide woven softshell or a polyester blend stretch knit.

e. Center Back Panel – A ventilation panel of polyester knit mesh or laser cut vent holes in a softshell woven are often used in the upper back.

f. Armpit Panels – Inner armpit panels of polyester or polyester/elastane knit mesh provide ventilation.

g. Outer Arm Panels – Wind resistance is their primary function. They are usually constructed of a multilayered softshell with an outer layer of polyester or polyamide woven softshell and inner fleece layer. Sometimes a durable water repellent (DWR) finish is applied to increase water resistance.

h. Inner Arm Panels – Inner arm panels of polyester knit, polyester/elastane knit or a merino wool/polyester knit blend provide stretch for movement.

i. Lower Back Panel – The lower back is usually extended farther down than the front to better keep the wind from entering while moving. This panel is usually stretchy for ease of movement. It is often constructed of knits of either a merino wool/polyester blend, 100% polyester, or polyester/elastane. Sometimes it is made of a polyester or polyamide softshell woven.

j. Inner Lining – The inside is lined with a layer of polyester brushed knit fleece for warmth.

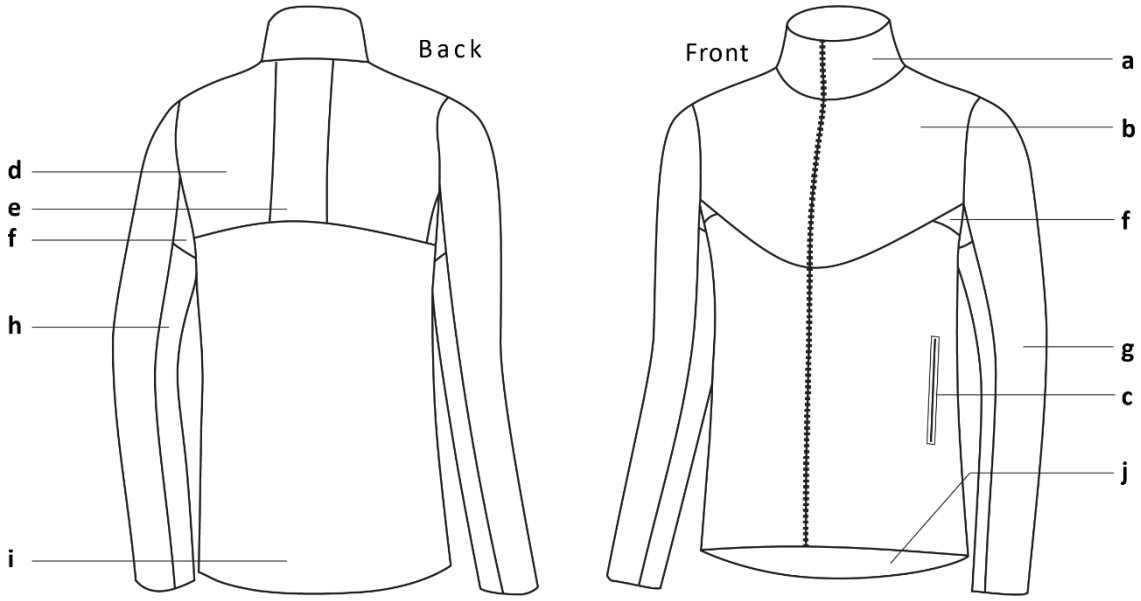


Figure 10 - Parts of a Cross-country Ski Jacket

3. Cross-country Ski Hat (Fig. 11)

    a. Main Upper – The main functions of the upper part of the hat are wind resistance and insulation. It is made of a polyester jersey knit or a merino wool/polyester/elastane jersey knit.

    b. Head Band – The lower part of the hat functions to keep the hat on the head and to keep the ears covered to protect them from wind and cold air. It is constructed of a ribbed knit or jersey knit of polyester or a merino wool/polyester/elastane blend.

    c. Inner Lining – The inner headband is often a layer of polyester brushed knit fleece and its main functions are insulation and to help with sweat wicking.

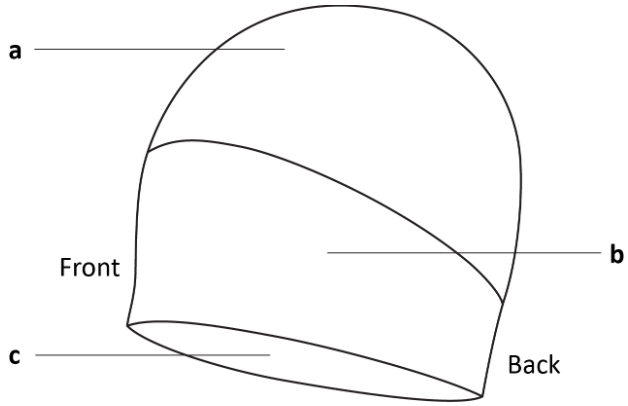


Figure 11 - Parts of a Cross-country Ski Hat

Skate Ski Apparel Line - Manufacturing

The current ski jacket and pants are manufactured by conventional means. The pattern pieces are scissor or laser cut. Most seams are sewn, but some are bonded, especially between synthetic woven fabric pattern pieces. Some of the seams on the front of the pants are taped and bonded on the inside.

The current ski hat is made either by cutting knit fabric pieces and serging them together or sewing with a flat stitch.

Intellectual Property - Existing Patents

Three existing patents and patent applications were found which could have an impact on this product space.

1. Adhesively Bonded Seams and Methods of Forming Them

The US patent US7455743B2, which is currently assigned to Mountain Hardware, Inc., is for stitchless adhesively bonded seams and the methods to form these seams. It covers the use of this type of seaming on fabrics or other sheet materials. (Google US7455743B2, n.d.)

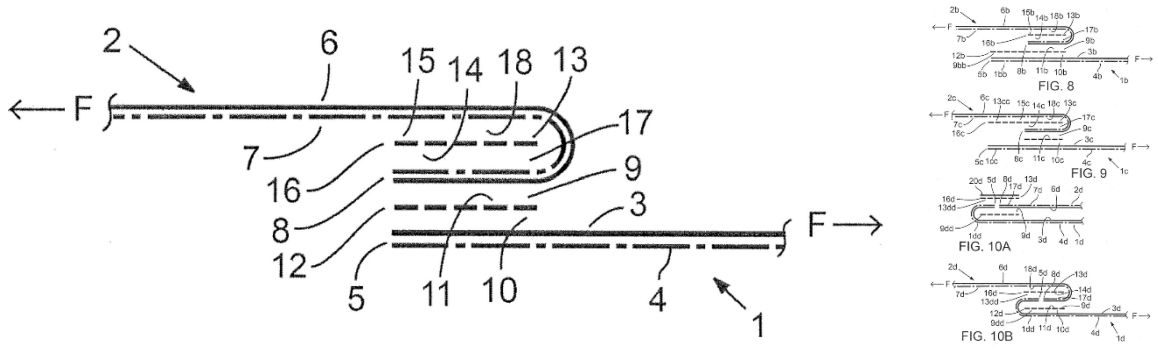


Figure 12 - Adhesively Bonded Seams and Methods of Forming Them (Google US7455743B2, n.d.)

2. Functional Composite Garment Materials

The patent application US20200216948A1 from 2020 is attempting to cover the use in apparel or footwear of any composite materials which "may have one or more functional properties including water repellency, antimicrobial function, insulation, moisture wicking, directional moisture transfer, body heat reflection, exterior heat reflection, body heat redistribution through conduction, as well as prevention of body heat loss through heat

conduction” (Google US20200216948A1, n.d.). The enforceability of such and over-reaching patent is questionable.

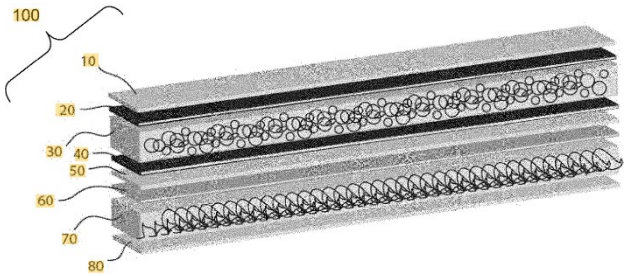


Figure 13 - Functional Composite Garment Materials (Google US20200216948A1, n.d.)

3. Garment Convertible into a Self-contained Bag

There is also an existing US patent US10945519B2 which covers any garment that can be converted into a bag by being folded into its own pocket (Google US10945519B2, n.d.). This may be a direction to avoid when considering the portability aspect of the jacket and hat.

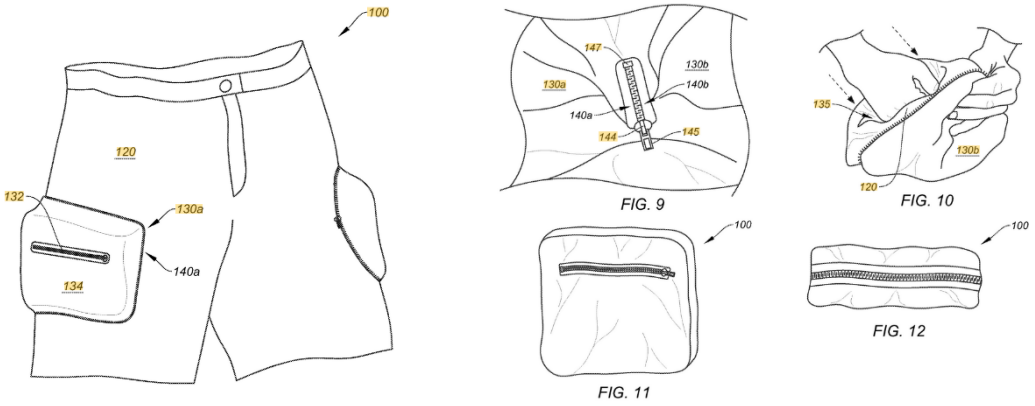


Figure 14 - Garment Convertible into a Self-contained Bag (Google US10945519B2, n.d.)

Benchmark Products and Competitive Landscape

1. Cross-country Ski Pants – State-of-the-Art Competitors

Figure 15 - Three State-of-the-Art Pants Competitors (Men's pro race, n.d.), (Bjorn Daehlie power pant, n.d.), (Swix Triac neo, n.d.)

a. Craft Pro Race 3/4 Zip XC Pants – This pair of cross-country ski pants retails for $160 and is made entirely out of Ventair 3-layer Polyester/Polyurethane Stretch Woven softshell material which they claim is windproof and waterproof. It has laser cut and taped seams for comfort and wind and waterproofness. There are no ventilation panels as they opted for laser cut ventilation holes. (Men's pro race, n.d.)

b. Bjorn Daehlie Power Pants – These retail for $120 and have a wind- and water-resistant softshell woven material in the front panels. In the upper rear, they have thinner polyester/elastane stretch woven panels for further stretch and better breathability than the softshell. They also have slanted ankle zippers for easier donning. (Bjorn Daehlie power pant, n.d.)

c. Swix Triac Neo Shell Pants – These cross-country pants retail for $295. They are constructed of windproof Polartec Neo Shell polyester woven softshell material on all except for the upper rear panels and behind the knees, which are a

polyamide/polyester knit allowing extra stretch for movement. They claim to have excellent breathability all over the garment, as well as having the ability to dry quickly. (Swix Triac neo, n.d.)

2. Cross-country Ski Jackets – State-of-the-Art Competitors

Figure 16 - Three State-of-the-Art Jacket Competitors (Gore-tex Infinium, 2022), (Men's pro velocity, n.d.), (Evolution gtx, n.d.)

a. Salomon Gore-Tex Infinium Windstopper Pro Jacket – This jacket retails for $200. It has windproof and water repellent panels layered with Gore Tex Infinium. There are strategically placed knitted stretch panels and it has laser cut ventilation holes in the upper back. (Gore-tex Infinium, 2022)

b. Craft Pro Velocity XC Jacket – This jacket retails for $185 and is mostly constructed of panels of a 3-layer windproof and waterproof softshell woven material which they claim has all over stretch. There is also a tricot back panel for breathability and perforated panels in the armpits for ventilation. (Men's pro velocity, n.d.)

c. Swix Evolution GTX Infinium Jacket – With a retail price of $270, this jacket also has windproof and water repellent panels layered with Gore Tex Infinium. It has a

knitted back panel for stretch and mesh knit panels in the armpits for ventilation. (Evolution gtx, n.d.)

3. Cross-country Ski Hats – State-of-the-Art Competitors

Figure 17 - Three State-of-the-Art Hat Competitors (Active extreme, n.d.), (Active - men's beanie, n.d.), (Swix Triac pro, n.d.)

a. Craft Active Extreme X Wind Hat – Retailing for $40, this hat has a wind-stopping tight polyester knit front panel and air-trapping polyester channel (ribbed) knit for warmth in the back. It is 100% polyester, but 39% is Coolmax polyester for sweat-wicking and cooling. (Active extreme, n.d.)
b. Salomon Active Beanie– This quick-drying hat is $25 and its exterior is made entirely of a 91% polyester/9% elastane knit for comfort and stretch, with a brushed fleece interior for warmth. (Active - men's beanie, n.d.)
c. Swix Triac Pro Hat – This $40 cross-country ski hat is a fully seamless 95% polyester/5% elastane knit with a mesh knit on top for breathability and a thicker double-knit over the ears for warmth and wind protection. (Swix Triac pro, n.d.)

Strengths, Weaknesses, Opportunities and Threats – SWOT Analysis of Benchmarks

Taking an in-depth look at the benchmark products on the market is an essential part of this process. For each piece in the apparel line, two of the competitor products identified earlier are analyzed, looking into the strengths of their functionality, and determining their weaknesses and any opportunities and threats which may exist for improvement and innovation. They are broken down by parts and considered against the project goals of creating technical apparel specific to the needs of recreational skate skiing males aged 50 and up.

1. Cross-country Ski Pants (Figs. 18-19)

Craft
Pro Race 3/4 Zip
XC Pants
$160

	STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
WAISTBAND	- Wide elastane polyester knit waistband for comfort - Holds up pants well	- Width and thickness contribute to increased sweating - No ventilation within waistband	- Design a waistband that tackles the issue of ventilation	- Customers who experience chafing and discomfort from their non-ventilated waistband may turn away from the brand
UPPER REAR PANELS	- Has a crotch gusset for some added give	- All panels made of same 3-layer softshell stretch woven, so areas needing more stretch are not addressed - Not made for skate movements	- Placing stretch panels where extra stretch is needed, especially where it's needed for skate skiing, will make the pants more fitting for the sport	- Competitors who have pants with strategically placed stretch panels could lure potential users away
REAR VENT PANEL	- Laser cut vent holes hidden inside horizontally zippered opening	- Using one fabric with low breathability and laser cutting in a few areas does not provide much ventilation	- Placing ventilation panels where they are needed, will make the pants more fitting for the sport	- Competitors who have pants with strategically placed ventilation panels could lure potential users away
FRONT PANELS	- Windproof and waterproof panels in front where the wind hits hardest	- All panels made of same 3-layer softshell stretch woven, so areas needing more or less wind resistance are not addressed	- More strategic placement of materials where they are needed is a big opportunity	- Competitors with more strategic use of materials are a threat
LEG CUFFS	- Long zipper up each leg for easy donning - Hook & loop strap for snug fit to boot	- Hook & loop can wear out over time	- Using a locking zipper at the bottom of each leg instead of hook & loop could be a better design	- Using a material that wears out like hook & loop could make the garment seem cheaper and less technical

Figure 18 - SWOT Analysis of Craft Pro Race 3/4 Zip XC Pants (Men's pro race 3/4 zip xc ski pants, n.d.)

Bjorn Daehlie Power Pants $120

	STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
WAISTBAND	- Silicone stays inside waistband hold up pants well	- Gathered elastic waistband less comfortable than others - Thickness contributes to increased sweating - No ventilation within waistband	- Designing a more comfortable and wider waistband with ventilation would be more appropriate for use in sport	- Customers who experience chafing and discomfort from their non-ventilated waistband may turn away from the brand
UPPER REAR PANELS	- Thinner polyester/elastane stretch woven fabric with more breathability than rest of garment - Provides good stretch	- The stretch woven does not provide much breathability - Not made for skate movements	- A more breathable panel, possibly a knit, would be better in this area - Designing for the specific needs of the sport is a huge opportunity	- Could lose buyers to competitors with more breathability
REAR VENT PANEL	- N/A	- Not having vent panels and just depending on the breathability of the stretch panel below does not provide much ventilation	- Placing ventilation panels where they are needed, will make the pants more fitting for the sport	- Competitors who have pants with strategically placed ventilation panels could lure potential users away
FRONT PANELS	- Wind and water resistant polyester stretch woven panels in front where the wind hits hardest	- Windproof would be better than wind resistant	- Could explore windproof fabrics for front panels	- Could lose out to competition who uses more advanced materials
LEG CUFFS	- Slanted ankle zippers for fit over boots		- This type of leg cuff opening is ideal	

Figure 19 - SWOT Analysis of Bjorn Daehlie Power Pants (Bjorn Daehlie power pant, n.d.)

Current benchmark pants were designed for classic cross-country skiing. The opportunities exist to design areas of stretch in the buttocks, back of the thigh and crotch specifically for skate skiing movements. There are also opportunities to design for improved comfort, especially regarding ventilation, particularly in the waistband and in back below the waistband. An angled leg zipper for easy donning and wind-resistant panels in the front were also identified as beneficial.

2. Cross-country Ski Jackets (Figs. 20-21)

Salomon Gore-Tex Infinium Windstopper Pro $200

	STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
COLLAR	- Fully zippered collar goes part-way up neck for warmth and wind control	- Back of collar may be too high for power stance	- Design high zip collar which dips in back slightly to match athlete in power stance	- Competitors with more consideration for skate skier needs may take part of market share
SHOULDER & CHEST PANELS	- Windproof softshell where it is needed in front and on shoulders - Softshell has 4-way stretch - Bonded seams for rain and wind resistance	- Not designed for skate movements	- Designing for the shoulder movement needs of a skate skier would be beneficial	- Competitors with more consideration for skate skier needs may take part of market share
FRONT POCKETS	- 2 zippered hand pockets for storage and comfort when needed - 1 vertical zippered chest pocket for storage	- Hand pockets are placed a little too high for comfort	- Design zippered hand pockets in a better, more comfortable position	- Small differences in comfort can be a big enough issue for consumers to look elsewhere
MAIN BACK PANEL	- Thinner 4-way stretch woven provides more stretch than the softshell panels - Bonded seams for rain and wind resistance	- May not be enough stretch in back of the shoulders - Not designed for skate movements	- Designing for the shoulder movement needs of a skate skier would be better	- Competitors with more consideration for skate skier needs may take part of market share
CENTER BACK VENT PANEL	- Laser cut ventilation holes in center upper back	- Ventilation holes are few and open to the elements	- Designing for more functional ventilation in this area would be beneficial	- Competitors with more consideration for ventilation needs may lure away buyers
ARM PIT PANELS	- Stretchy brushed knit for breathability and movement	- Not as breathable as a stretch mesh knit would be	- Designing for more functional ventilation in this area would be beneficial	- Competitors with more consideration for ventilation needs may lure away buyers
OUTER ARM PANELS	- Windproof softshell where it is needed		- This is ideal placement for windproof panels	
INNER ARM PANELS	- Stretchy brushed knit for breathability and movement	- Stretch panels do not extend past the inner elbow	- Design stretch panels that fully extend down the inner arm	- Competitors with more consideration for skate skier needs may take part of market share
LOWER BACK PANEL	- Dropped back hemline for protection from wind		- The dropped back hemline is ideal	
INNER LINING	- Brushed inner lining of softshell for softness and warmth	- No sweat-wicking ability	- Design lining with sweat-wicking in mind	- Competitors with more consideration for sweat management needs may lure away buyers

Figure 20 - SWOT Analysis of Salomon Gore Tex Infinium Windstopper Pro Jacket (Gore-Tex Infinium Wind-stopper pro, 2022)

Craft Pro Velocity XC Jacket $185

	STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
COLLAR	- Fully zippered collar goes part-way up neck for wind control	- Back of collar may be too high for power stance	- Design high zip collar which dips in back slightly to match athlete in power stance	- Competitors with more consideration for skate skier needs may take part of market share
SHOULDER & CHEST PANELS	- Windproof and waterproof softshell where it is needed in front and on shoulders - Softshell has 4-way stretch	- Not designed for skate movements	- Designing for the shoulder movement needs of a skate skier would be beneficial	- Competitors with more consideration for skate skier needs may take part of market share
FRONT POCKETS	- 2 zippered hand pockets for storage and comfort when needed - 1 zippered chest pocket for storage	- Chest pocket would be more convenient turned 90 degrees	- Design a chest pocket in a vertical or diagonal orientation to be more convenient to open and close	- Small differences in comfort can be a big enough issue for consumers to look elsewhere
MAIN BACK PANEL	- Tricot warp knit for stretch and improved breathability	- May not be enough stretch in back of the shoulders - Not designed for skate movements	- Designing for the shoulder movement needs of a skate skier would be better	- Competitors with more consideration for skate skier needs may take part of market share
CENTER BACK VENT PANEL	- N/A	- Definite need for ventilation in this area	- Designing for more functional ventilation in this area would be beneficial	- Competitors with more consideration for ventilation needs may lure away buyers
ARM PIT PANELS	- Laser cut holes	- Holes are very small and more are needed to improve ventilation	- Designing for more functional ventilation in this area would be beneficial	- Competitors with more consideration for ventilation needs may lure away buyers
OUTER ARM PANELS	- Windproof and waterproof softshell where it is needed		- This is ideal placement for windproof panels	
INNER ARM PANELS	- Tricot warp knit for stretch and improved breathability		- This is ideal placement for stretchy and breathable panels	
LOWER BACK PANEL	- Slimmed back hemline for protection from wind	- Straight across hemline instead of dropped hemline does not protect against wind as well during movements	- Design a dropped lower hemline to increase wind protection when moving	- Competitors with more consideration for skate skier needs may take part of market share
INNER LINING	- Brushed inner lining of softshell for softness and warmth	- No inner lining in back - No sweat wicking ability	- Design lining with sweat-wicking in mind	- Competitors with more consideration for sweat management needs may lure away buyers

Figure 21 - SWOT Analysis of Craft Pro Velocity XC Jacket (Men's pro velocity xc ski jacket, n.d.)

These jackets are technical in their design and each one differs in the way they approach fulfilling the wearer's needs. Currently, no jacket exists which tackles the specific needs of a skate skier. Opportunities exist to create a jacket which allows for the particular movements of a skate skier, especially in the amount of stretch needed in the shoulders and inside the sleeves and armpits. Wind resistance in the front and hand pocket placement are other aspects to

consider. There are also opportunities to improve comfort by providing adequate ventilation in the armpits and upper back areas.

3. Cross-country Ski Hats (Figs. 22-23)

Ski hats need to keep the wearer warm, but also stay on comfortably while the athlete is moving. Opportunities also exist to improve the comfort of the wearer by addressing sweat wicking and ventilation, since a skate skier can get overheated.

Craft Active Extreme X Wind Hat $40

	STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
MAIN UPPER	- Entire front panel is a wind resistant stretch knit - Lightweight fully synthetic knit	- Only passive ventilation through knit upper	- Opportunity exists to design ventilation that the user can open and close as needed	- Competition who better address ventilation could take away market share
HEADBAND	- Front part of headband is integrated into wind resistant upper panel - Rear of headband drops over ears and is made of a channel knit for wind protection and warmth	- Slicker synthetic knit can ride up over time	- Design a hat that does not ride up while being used in sport - The drop over the ears is an ideal design	- Competitors with more consideration for skate skier needs may take part of market share
INNER LINING	- Interior is entirely synthetic channel knit for warmth - Coolmax for sweat wicking - Flatlock seams for comfort	- Interior is not as soft or comfortable as competitors	- Design a soft lining for comfort	- Could lose out to competition who better address comfort

Figure 22 - SWOT Analysis of Craft Active Extreme X Wind Hat (Active extreme x wind hat, n.d.)

Salomon Active Beanie $25

	STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
MAIN UPPER	- Warm micro fleece - Soft for comfort - Quick drying	- Ventilation is not addressed - Wind resistance is not addressed	- Opportunity exists to design ventilation that the user can open and close as needed - Placement of wind resistant fabric in the front would be ideal	- Competition who better address ventilation and wind resistance could take away market share
HEADBAND	- Warm micro fleece - Soft for comfort	- Could come down over ears more	- Design the headband part so that it drops down over the ears	- Competitors with more consideration for skate skier needs including ear warmth may take part of market share
INNER LINING	- Micro fleece for warmth and comfort	- Sweat wicking is not addressed	- Design with a sweat wicking material	- Could lose out to competition who better address sweat wicking needs

Figure 23 - SWOT Analysis of Salomon Active Beanie (Active men's beanie, n.d.)

Current Trends – Color, Graphics, and Branding

Currently, men's cross-country ski apparel tends to be made in deep, saturated hues of blues, reds, blacks, and teal greens. These are often accented by whites, silvers, or medium tan earth tones. Current graphics tend to be simple color blocking with accents of colored bonded tape. Branding and logo applications tend to be single- or two-color, often heat-bonded, and rather large. They are sometimes reflective and usually on the front or back of the torso and sometimes down the side of an arm or leg.

Figure 24 - Current Trends in Color, Graphics, and Branding (Swix cross jacket - men's, n.d.), (XC World Cup beanie, n.d.), (Gore-Tex Infinium Windstopper pro, n.d.), (Men's Poursuite warm Nordic ski jacket, n.d.)

Future Trends – Color, Graphics, and Branding

Future color and graphics trends have been released by trend predicting firm WGSN for snow sport for autumn/winter 2023-24. For what they are calling an Active Creative Reset, the color trends are bold and bright with bitter lemon, beacon orange, and galactic cobalt blue, which are being contrasted with muted hues like pumice, sage leaf green and oceanic blue-green (Kostiak, 2022). This is the color direction that the apparel line will be following.

WGSN also states a trend toward more social media-friendly looks and metaverse-inspired aesthetics with a move toward creative modularity and adjustability (Kostiak, 2022). Instead of blatant graphics, WGSN has published in their active materials forecast for 2023-24 that the trend is toward more dimensional, linear forms (Browning & Kostiak, 2022). These linear forms will be incorporated into the apparel designs along with metaverse-inspired updated, futuristic color blocking.

For the future, a more strategic and design-specific use of branding would be more desirable than the oversized logos of the current trend. Placing the branding along the seams or on cuffs or garment edges would have more stylistic impact and would make for a more memorable and meaningful use. The future logo and brand name will be inspired by the sport of skate skiing and evoke the movement techniques specific to the sport like the V1, V2 and V2 Alt skate techniques.

Figure 25 - Future Trends in Color, Graphics, and Branding (Kostiak, 2022), (Silva, 2013), (Hodgson, 2016), (Browning & Kostiak, 2022)

Athlete Insights

Insights from males aged 50 and up who skate ski recreationally have been gathered through use of an online survey and through a personal interview. The survey asks their opinions and feelings about the apparel they currently wear while skate skiing and delves into their needs and wants for such apparel. The athletes have been found by reaching out on online cross-country skiing forums. The data will be used to answer the question as to whether or not the suggested current apparel problems have been perceived by the recreational athletes and to determine if there are other, unforeseen issues with the design and function of their current apparel. The survey questions are on Figs. 26 and 27 below.

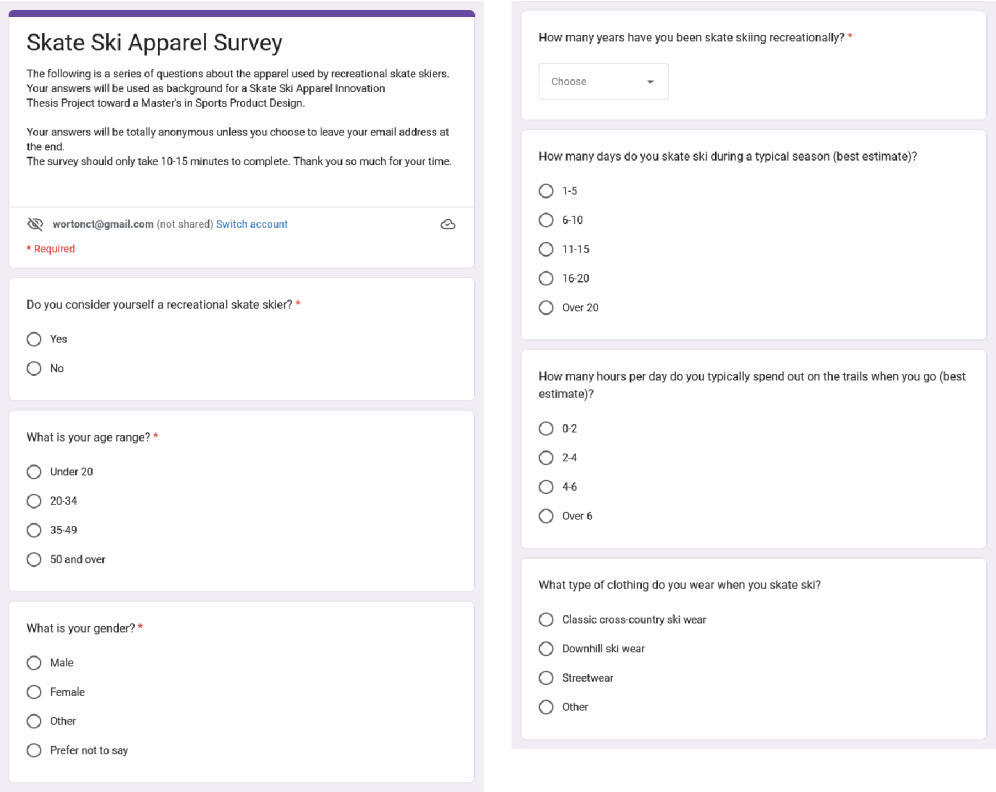


Figure 26 - Survey Questions Part 1

If you answered "Other" on the question above, please briefly explain what you typically wear to skate ski.

Your answer

What type of jacket (softshell, fleece, puffer, etc.) do you currently wear for skate skiing?

Your answer

What type of pants (cross-country ski pants, tights, sweats, etc.) do you currently wear for skate skiing?

Your answer

What do you typically wear on your head while skate skiing?

- Nothing
- Beanie
- Headband
- Other

What do you wear as a baselayer while skate skiing?

- Fitted baselayer
- T-shirt
- Nothing
- Other

How many layers do you typically wear on your upper body while skate skiing?

- 1
- 2
- 3
- Over 3

Do you ever feel too hot while you are skate skiing?

- Yes
- No

Do you ever feel too cold while you are skate skiing?

- Yes
- No

Do you ever remove layers to cool off while you are out on the skate ski trails?

- Yes
- No

If you answered "Yes" to the question above, how often (estimated percentage of times) do you take off layers while skate skiing?

- Less than half the time
- More than half the time
- Almost every time

Do you feel that your skate skiing apparel offers adequate ventilation or airflow?

- Yes
- No
- Unsure

Do you feel that your current jacket or outer layer allows for all of the movements you need to make while skate skiing?

- Yes
- No
- Unsure
- I do not wear a jacket or outer layer.

Do you feel that your current pants allow for all of the movements you need to make while skate skiing?

- Yes
- No
- Unsure

Do you feel that your current baselayer allows for all of the movements you need to make while skate skiing?

- Yes
- No
- Unsure
- I do not wear a baselayer.

Do you feel that your current skate skiing apparel limits you in any way?

- Yes
- No

If you answered "Yes" to the question above, please briefly explain how you feel your apparel limits you.

Your answer

Is there anything that you would want to change about your skate skiing apparel?

- Yes
- No

If you answered "Yes" to the question above, please briefly explain what you would like to change about your skate skiing apparel.

Your answer

If you would like to be contacted, please leave your email addres below.

Your answer

Figure 27 - Survey Questions Part 2

Based on 18 responses and one interview of recreational skate skiing males aged 50 and over, the following has been ascertained.

1. What the Athletes Wear

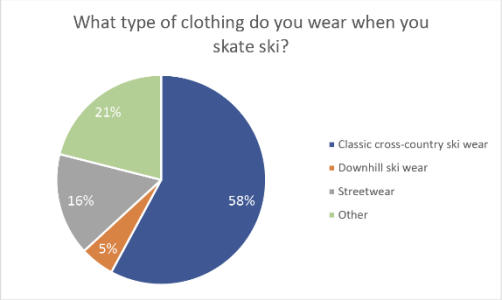


Figure 28 - Type of Clothing Skate Skiers Wear

Most of the responders (58%) wear classic cross-country ski wear. This percentage could be skewed because most of the athletes were found through a cross-country skiing forum. One of the responders stated that he wears biking tights, but they do not work well for the sport.

2. What the Athletes Feel About the Function of Their Apparel

Almost half of the respondents said that their current skate skiing apparel limits them in some way. Only 48% of them said that their pants allowed for all the movements they needed and 53% said their jackets allowed for all the movements they needed.

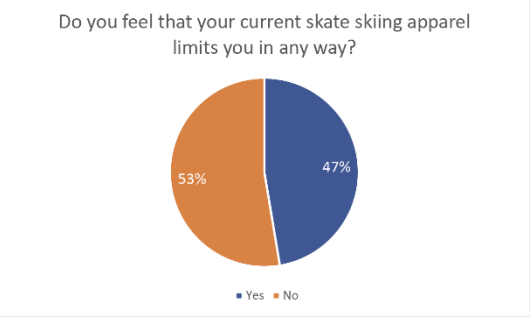


Figure 29 - Apparel Limiting Athletes

Figure 30 - Movement Allowance by Pants and Jacket

3. The Athletes' Experience with Being Too Hot or Cold

Figure 31 - Athletes Feeling Hot or Cold While Skate Skiing

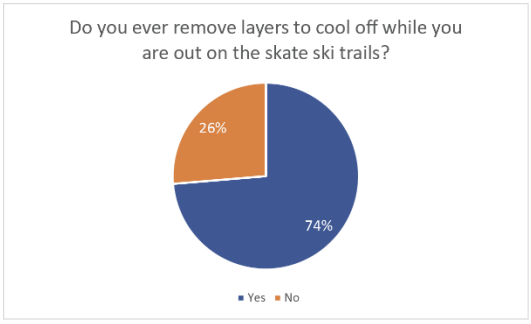


Figure 32 - Athletes Removal of Layers

An overwhelming 84% of the athletes said they have felt too hot while skate skiing, while 47% said they have felt too cold. From this it seems fairly clear that whatever they are wearing is helping keep them warm, but they overheat while out skiing. When asked if they ever need to remove layers while skate skiing, 74% responded that they do. Of those, 64% said that they remove layers more than half the time or almost every time.

4. What the Athletes Feel About the Ventilation of Their Apparel

Of the athletes who responded, 58% answered that their apparel does not offer adequate ventilation or airflow. Sweating easily was a complaint stated by some of the athletes.

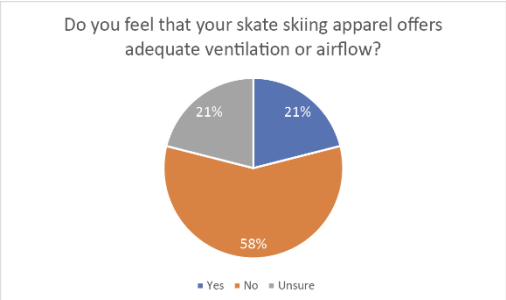


Figure 33 - Apparel Ventilation

5. What the Athletes Would Change About Their Apparel

When asked what they would change about their apparel, one respondent focused on problems he perceived with his headwear. He stated: "I don't like hoods because they don't keep my ears warm enough. I start out with a beanie, but have to remove it because my head gets too sweaty. Then my ears get cold, so I have to put it back on. Thought about trying a headband, but haven't used one." This was quite the insight and will definitely influence design direction.

Metrics to Be Tested and Definition of Success

In alignment with the earlier stated problem question, three metrics will be measured by testing: mobility, ventilation, and ability to cool off. Mobility will be tested regarding how the garments stretch to allow for the range of motion necessary for skate skiing. Ventilation will be tested regarding how well the garments allow vapor to pass through them. Visualization of heat loss with infrared videography will be used to assess the garments' ability to allow for rapid cooling, but not for numerical analysis of this metric. Instead, the subjective views of the wearer will be assessed to determine their perceived ability to cool off.

The prototypes will be deemed successful in achieving their goals if they are determined to have 3 percent more stretch in the areas tested, ten percent more vapor passage (thus, better ventilation) through the garment in the areas tested, and a twenty percent increase in the perceived ability to cool down.

Performance Testing Plans

1. Mobility Testing

The objective of this testing is to determine the degree to which the garments will allow for skate ski movements. The products to be tested for mobility are the pants and jacket. The planned testing location is the Nucleus Lab in the White Stag Building in Portland. The testing procedure will be as follows:

a. Proper consent will be gained in writing for the human mobility testing subject before testing begins.
b. A stretchable grid of 2” x 2” squares will be drawn onto the surface of the garment in the areas that need stretch the most when moving. These areas were determined by the in-field use of the benchmark products, followed by interviewing the testing athlete. The areas are the lateral of the thigh of the pants, and the back of the shoulder in the trapezius muscle region of the jacket.
c. Videos will be taken as the subject starts in a standing rest position and moves into a pose which exaggerates (for the lateral thigh and back of the shoulder) the positions required while moving to skate ski, and this process will be repeated a total of three times. From the video, screen captures will be taken and grid points will be measured as a distance from a fixed reference point near the middle of the panel on the garment. The data from the three trials will be averaged. From that data, the amount of stretch at each grid point will be calculated as a percentage over the original distance. This process will be completed for the jacket and pants.

d. This method will be completed on the benchmark products and the entire process then will be repeated later on the prototypes and the results will be compared.

2. Ventilation Testing

The objective of this testing is to determine how much the garment tested will allow for the movement of vapor through it. The products to be tested are the pants, jacket, and hat. The pants will be tested in the back of the waistband and in the venting area just below the back of the waistband. The jacket will be tested in the upper back venting area. The beanie will be tested on the top center. The planned testing location is the Nucleus Lab in the White Stag Building in Portland. The testing procedure will be as follows:

a. The product to be tested will be placed onto a hollow, porous mesh body form.
b. A specific amount of dry ice pellets will be placed into an open container and a specific amount of warm water will be added. The container will be placed inside the mesh form near the area being tested. The same container, same amount of water at the same temperature, and same number of dry ice pellets will be used for every test. The testing will all be done withing a few hours in the same location. This is all to ensure (as closely as possible) identical amounts of CO_2 vapor to be released at identical rates for each testing of each garment.
c. The visual data of the vapor moving through the garment will be analyzed by converting the full-color screen captures to two-color black and white so that the vapor passing through the garments can be clearly distinguished. From the converted images, the level of darkness or lightness of the specific rectangular space

in the screen capture will be determined as numeric percentage through a pixel analysis. This will be done for 5 screen captures (each one second apart) and averaged.

d. This entire process will be done at first for the benchmark products and later for the prototypes. Then the numerical percentages gained from the video observations will be compared.

3. Heat Release Testing

The objective of this testing is to visualize heat release ability of the jacket and beanie in warm up, peak performance and cool down metabolic phases. The athlete will be tested while running on a laboratory treadmill. Because our available apparatus, a FLIR infrared camera, is limited in its ability to give accurate temperature numerical values, the images obtained will be used for visualization purposes. The planned testing location is the Nucleus Lab in the White Stag Building in Portland. The testing procedure will be as follows:

a. Proper consent will be gained in writing for the human testing subject before testing begins.
b. The FLIR infrared camera, attached to an iPhone, will be set up on a tripod in front of a treadmill to capture the front of the torso and head of the athlete.
c. The athlete will wear the same polyester knit baselayer and polyester/cotton knit blend underwear for all testing. They will wear the jacket, pants and beanie for the tests.

d. The athlete will begin at a slow pace (set at 3 on the lab treadmill) to represent the warming up phase and will be captured for 2 minutes. Then they run at a moderate pace (set at 7 on the lab treadmill) for 10 minutes to represent the peak performance phase. Finally, their pace will be decreased to a fast walk (set at 2 on the lab treadmill) to represent the cool down phase. At that time, they will unzip the jacket when wearing the benchmark products. When testing the prototypes, they will convert the jacket and beanie into their open phases for the cool down visualization.
e. This will be repeated for the benchmark products and the prototypes. The video captures will be used to visually compare between the benchmarks and the prototypes.

4. Field Testing for Perceived Mobility, Comfort in Regard to Heat and Vapor Release, and Ability to Rapidly Cool Down

The objective of this testing is to ascertain the subjective thoughts of the wearer in regard to how the garments feel when being worn while skate skiing. The products to be tested are the pants, jacket, and hat. The planned location of the testing is Mount Hood Meadows Nordic Center. The testing procedure will be as follows:

a. Proper consent will be gained in writing for the human mobility testing subject before testing begins.
b. The jacket, pants, and beanie will be worn by the athlete/wear tester, who will skate ski on trails for a minimum of 2 hours. They will be instructed to do whatever they

want with the garments to help cool down when they feel like they need to do so. In the case of the prototypes, they will be shown in advance how to convert the beanie and jacket prototypes to their open phases. The tester will wear the same undergarments for all trials, which in this case is a pair of polyester/cotton blend briefs and a polyester knitted baselayer.

c. They will be recorded on video and photographed.

d. Afterward, they will be interviewed with questions covering their views on how the garments perform and feel in regard to their ability to cool themselves off when approaching a state where they start to feel overheated. To have numerical data, their responses will be recorded on a Likert scale of 1 to 5.

e. Additional photographs and videos will be made in action of any problem areas they point out, to help guide the design of the prototypes.

f. This testing and interviewing will be completed on all three benchmark products. The same procedures will be repeated on the prototypes later and the numerical results will be compared.

Benchmark Products Testing

1. Mobility Testing

Mobility testing was completed on the benchmark jacket and pants as described in the Performance Testing Plan section. Results (Fig 34) are as follows.

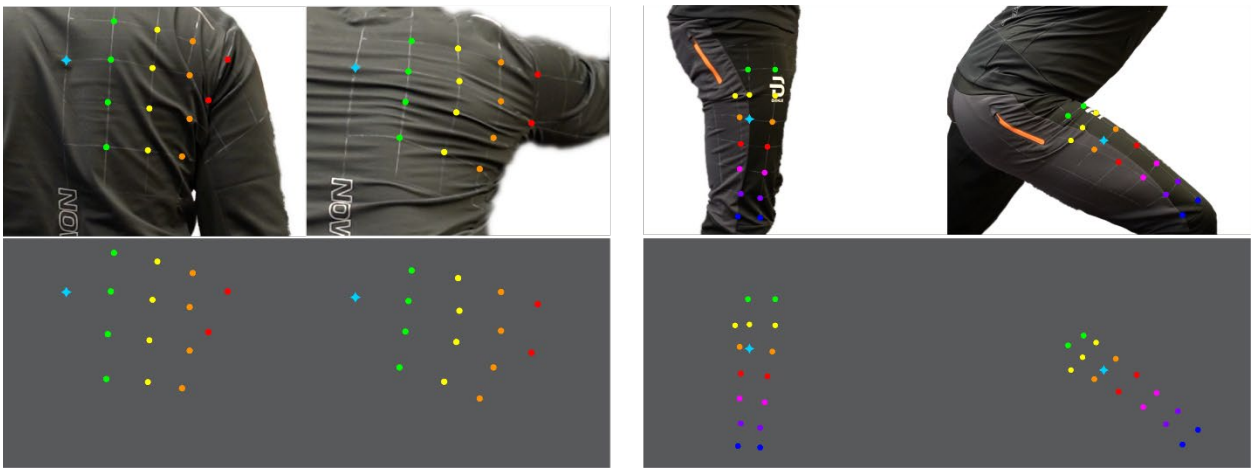


Figure 34 – Benchmark Jacket and Pants Stretch Testing

The measurements taken from the screenshots were put into a table and percent of stretch was calculated (Fig. 35). Note that the units in the table do not matter because all measurements of stretch are calculated as a percentage of the unstretched garment.

Jacket	Green	Yellow	Orange	Red
1	0	8.3	13.4	12.7
2	20.5	21.1	20.2	24.8
3	1.9	14.3	5.0	x
4	-13.3	0.9	6.9	x

Pants	1	2	3
Green	x	-14.3	-28.6
Yellow	20.8	4.8	-16.7
Orange	22.2	x	25.0
Red	0	x	0
Pink	6.8	x	2.0
Purple	12.1	x	1.4
Blue	12.7	x	9.2

Figure 35 – Benchmark Jacket and Pants Percentage Stretch Calculated

The main takeaway for the jacket was that the highest percentage of stretch was 24.8 percent. For the pants, the highest percentage of stretch was 25.0 percent.

2. Ventilation Testing

Ventilation testing was completed on the benchmark jacket, pants, and beanie as described in the Performance Testing Plan section. Results are shown below (Fig. 36).

Figure 36 – Ventilation Testing of Benchmark Pants, Jacket, and Beanie

Videos were recorded of the back vent of the jacket, the (ventless) back area above the buttocks of the pants, and the top of the beanie while vapor was created inside the benchmark product. Vapor was recorded leaving the jacket back vent and the top of the beanie. No vapor was seen exiting the back of the pants.

3. Heat Release Testing

Infrared imaging was completed on the benchmark jacket, pants, and beanie in the lab as described in the Performance Testing Plan section. The results are shown below (Fig. 37)

Figure 37 – Infrared Imaging of Benchmark Pants, Jacket, and Beanie

The main takeaways are that the benchmark jacket shows heat being released once it was unzipped in the cool down phase but held in heat otherwise.

4. Field Testing for Perceived Mobility, Comfort in Regard to Heat and Vapor Release, and Ability to Rapidly Cool Down

This testing was completed on the benchmark jacket, pants, and beanie as described in the Performance Testing Plan section. The conditions were 29 degrees F, cloudy, snowing and gusty at the beginning and became 32-33 degrees F, sunny and clear with low winds by the end of testing. The following questions were asked after testing and answers recorded.

Do you feel the jacket allowed you to make all movements necessary to skate ski?
● **Yes** ○ **No**

While skate skiing, were there any places on the jacket that you feel could use more or less "give" to allow for better movements? If so, where?
● **Yes** ○ **No** **Too tight in the lats area behind the armpits.**

Do you feel the pants allowed you to make all movements necessary to skate ski?
● **Yes** ○ **No**

While skate skiing, were there any places on the pants that you feel could use more or less "give" to allow for better movements? If so, where?
● **Yes** ○ **No** **I sometimes felt pulling from inside the groin area to outside knee.**

Were there any parts, seams, or fabric panels on the jacket that felt uncomfortable while skate skiing and if so, where?
○ **Yes** ● **No**

Were there any parts, seams, or fabric panels on the pants that felt uncomfortable while skate skiing and if so, where?
○ **Yes** ● **No**

Were there any parts, seams, or fabric panels on the beanie that felt uncomfortable while skate skiing and if so, where?
○ **Yes** ● **No**

Do you feel that the jacket, pants, and beanie offered adequate wind protection?
● **Yes** ○ **No**

Approximately how long were you skate skiing before you started to sweat?
Within 20 minutes

Did you ever become uncomfortably sweaty and if so, how long were you skate skiing before you noticed that feeling?
● **Yes** ○ **No** **Within 1 hour**

Did you ever feel overheated while skate skiing in the jacket, pants, and beanie?
● **Yes** ○ **No**

If so, once you became overheated, how did you feel once you had removed the jacket and beanie?
I felt instant relief.

When you removed the jacket, how did you stow it each of the 4 times?
Tied around my waist all 4 times.

When you removed the beanie, how did you stow it each of the 4 times?
Once tucked into back of pants waistband, twice into side of waistband, and once in jacket chest pocket.

Was there anything particularly annoying about your stowage of the jacket and/or beanie? If so, please elaborate.

● **Yes** ○ **No** **The jacket kept coming loose and almost fell off a few times.**

For the following questions, please rate the garments on a comfort scale from 1 to 5, with 1 being very uncomfortable and 5 being very comfortable.

While skate skiing, how comfortable did you feel wearing the jacket considering only your sweating experience and the ability of the garment to ventilate?

2

While skate skiing, how comfortable did you feel wearing the pants considering only your sweating experience and the ability of the garment to ventilate?

3

While skate skiing, how comfortable did you feel wearing the beanie considering only your sweating experience and the ability of the garment to ventilate?

3

How comfortable did you feel wearing the jacket considering only your ability to move in all positions necessary to skate ski?

4

How comfortable did you feel wearing the pants considering only your ability to move in all positions necessary to skate ski?

4

How comfortable did you feel overall wearing the jacket while skate skiing?

2

How comfortable did you feel overall wearing the pants while skate skiing?

4

How comfortable did you feel overall wearing the beanie while skate skiing?

3

Please rate your overall feeling of comfort using the jacket, pants and beanie in regard to wind protection.

4

Please rate your overall feeling of comfort using the jacket, pants and beanie in regard to their ability to allow all needed movements.

3

Please rate your overall feeling of comfort using the jacket, pants and beanie in regard to ventilation and heat release (passive cooling).

2

Please rate your overall feeling of comfort using the jacket, pants and beanie in regard to their ability to allow you to cool off (to prevent overheating).

2

Please rate your overall feeling of comfort using the jacket, pants and beanie.

4

The main takeaways from the questions were that the athlete began to sweat within 20 minutes of skiing and became “uncomfortably sweaty” within one hour. He noted no problems

with types of seams or seam placement in regard to comfort. He felt that the pants and jacket allowed for the movements needed, but that there could have been more give in the lats area and inner and outer thigh between the groin and lateral of the knee. Also, all 4 times he tied the sleeves of the jacket around his waist and let it hang down the back. Once he tucked the beanie into the back of his waistband, twice he tucked it on the side and once he zipped it into the jacket pocket before tying it around. The athlete said he felt “instant relief” as soon as he was able to remove the beanie and jacket after feeling overheated. He was also annoyed that the jacket kept coming untied and would start to slip off.

Body Mapped Functional Zoning

Langer's lines are topological lines denoting the direction of the collagen fibers of the skin (Byth, 2019). Throughout the body, they run perpendicular to the underlying muscle fibers (Fig. 38). Therefore, it makes sense to use the direction of the lines to guide in planning the patterns and placement of garment stretch panels, mimicking the way skin folds and stretches in bodily movements to take into account both linear stretch and rotation.

Figure 38 – Langer's Lines on an Avatar

It is crucial to refer to sweat maps such as this one in Fig. 39 for the placement of vents in the design of the garments.

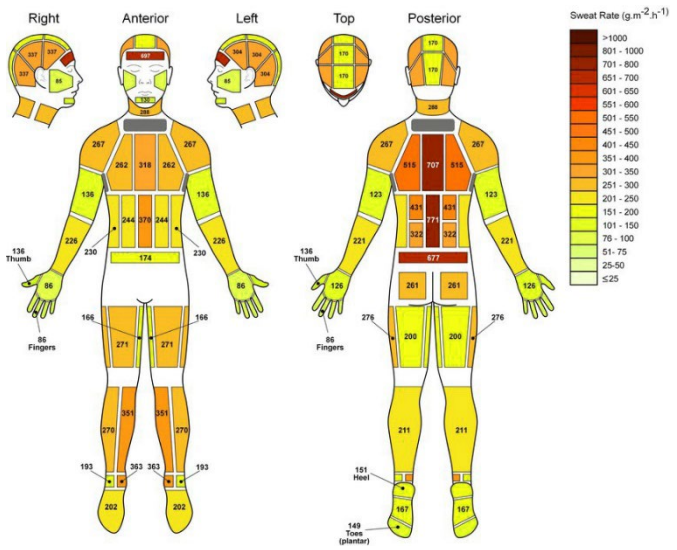


Figure 39 – Male Sweat Maps (Smith, 2011)

Body mapped functional zones for stretch, sweat/heat release, and wind blocking (Fig 40) were created using the athlete insights, the information gained from the benchmark testing, and the above research.

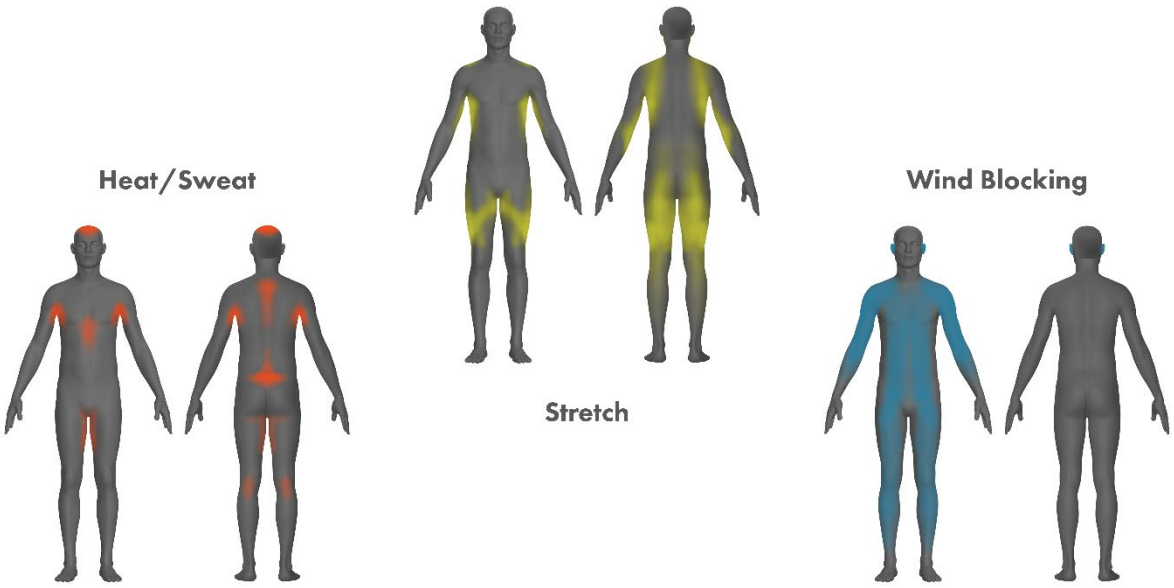


Figure 40 – Body Mapped Functional Zones

The zones point out a major challenge in the functional design of the planned garments. Wind blocking materials will be necessary for the front panels, but the superior wind blocking fabrics are multi-layered, treated wovens which offer little to no stretch. As shown in Fig. 40, stretch will be very necessary in the front, especially in the thighs and shoulders.

Design Ideation

Figure 41 –Early Jacket and Pants Sketches

Ideation proceeded through design sketches of the jacket and pants (Fig. 41) where various ideas of color blocking were explored. The concept of user-customized ventilation for the beanie was also explored along with various numbers and placements of vents and vent tubes (Fig. 42).

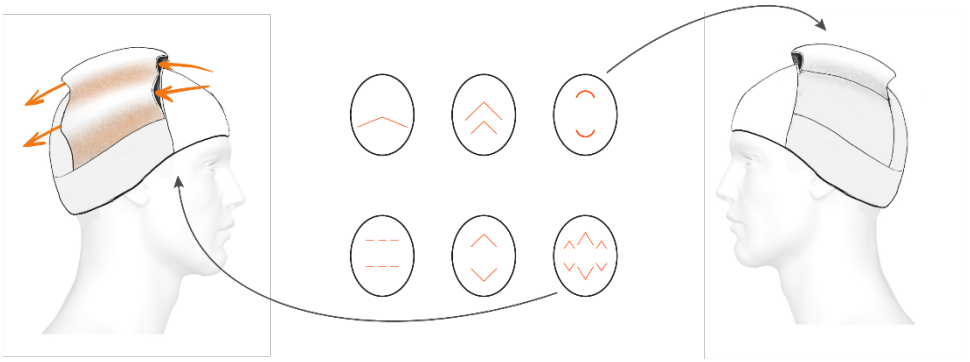


Figure 42 – Early Beanie Vent Exploration

Over time, the final sketches developed, as seen in Fig. 43 below.

Figure 43 – Later Design Exploration

Prototyping Process

The pants were first prototyped as shorts with various patterns and configurations of stretch panels until a satisfactory fit and function was achieved, then full pants were patterned and assembled. Stretch inserts were laser cut and built into the non-stretch wind-stopping panels of the pants and jacket by adhesive heat bonding them into the main pieces. Rear vent panels in the jacket and pants were also created by laser cutting and heat bonding. A chest pocket was also laser cut and heat bonded along with a fully bonded pocket zipper. The main jacket zipper and the boot zippers in the pants legs were sewn in. A waistband with rear ventilation was created for the pants as well as stretch mesh pit vents in the jacket.

The beanie pattern was created based on the zones for wind blocking, stretch and ventilation required. The main place ventilation is needed is on the top of the head, so several methods of head top vent shapes and sizes were explored. Multiple ideas for opening and closing the vents were also explored which included many iterations and combinations of 3-D printed TPU auxetic springs and magnets. Next, an interface-reinforced tunnel with front and back openings over a mesh panel was created.

After those prototypes, the patterns for the jacket and pants were reworked and the new prototypes were created with better fit, larger vent panels, a new system to open up the jacket, and more functional stretch inserts. The beanie was completely re-worked into a 2 level system with an inner mesh skullcap and outer stretch cap that can be folded back.

Most of the prototypes are shown below in Fig. 44.

Figure 44 – Stages of Prototyping

Prototype Testing and Comparison to Benchmark Products

1. Mobility Testing

Mobility testing was completed on the prototype jacket and pants as described in the Performance Testing Plan section. Results (Fig 45) are as follows.

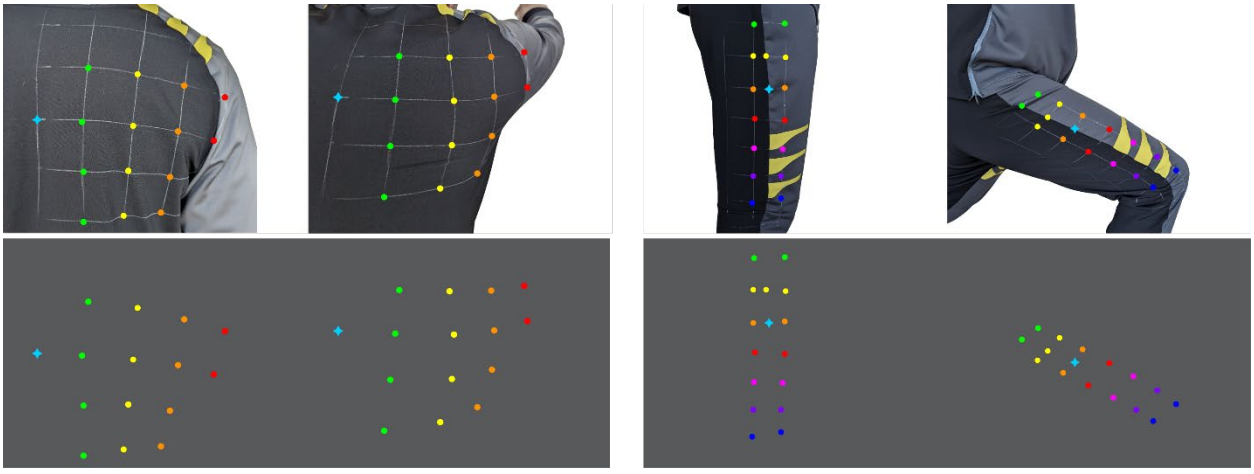


Figure 45 – Prototype Jacket and Pants Stretch Testing

The measurements taken from the screenshots were put into a table and percent of stretch was calculated (Fig. 46). Note that the units in the table do not matter because all measurements of stretch are calculated as a percentage of the unstretched garment.

Jacket	Green	Yellow	Orange	Red
1	1.6	7.3	4.5	1.2
2	28.2	20.2	10.6	6.4
3	1.6	18.5	9.5	x
4	-2.0	5.3	3.7	x

Pants	1	2	3
Green	x	16.0	34.1
Yellow	0	11.5	23.1
Orange	0	x	7.7
Red	26.1	x	0
Pink	15.2	x	3.8
Purple	13.2	x	0
Blue	17.6	x	0

Figure 46 – Prototype Jacket and Pants Percentage Stretch Calculated

For the jacket, the highest percentage of stretch was 28.2 percent. For the pants, the highest percentage of stretch was 34.1 percent.

These results were compared to the benchmark jacket and pants. For the jacket, the main takeaways are that the prototype showed at most 28.2 percent stretch compared to 24.8 percent stretch of the benchmarks in the area tested. For the pants, the main takeaways are that the prototype showed at most 34.1 percent stretch compared to 25.0 percent stretch of the benchmark in the area tested. The prototype jacket stretched 3.4 percent more than the benchmark. The prototype pants stretched 9.1 percent more than the benchmark.

2. Ventilation Testing

Ventilation testing was completed on the prototype jacket, pants, and beanie as described in the Performance Testing Plan section. Results are shown below (Fig. 47).

Figure 47 – Ventilation Testing of Prototype Pants, Jacket, and Beanie

Videos were recorded of the back vent of the jacket, the back vent and mesh waistband of the pants, and the top of the beanie while vapor was created inside the prototypes. The vapor released was visually quite obvious and was recorded leaving the jacket back vent, the pants back vent and the top of the beanie. The planned pixel analysis proved unacceptable as data, but the differences between the prototypes and the benchmarks (in the Benchmark Products Testing section) are visually obvious. The prototypes showed superior passage of the vapor in all areas tested when compared to the benchmark products.

3. Heat Release Testing

Infrared imaging was completed on the benchmark jacket, pants, and beanie in the lab as described in the Performance Testing Plan section. The results are shown below (Fig. 48)

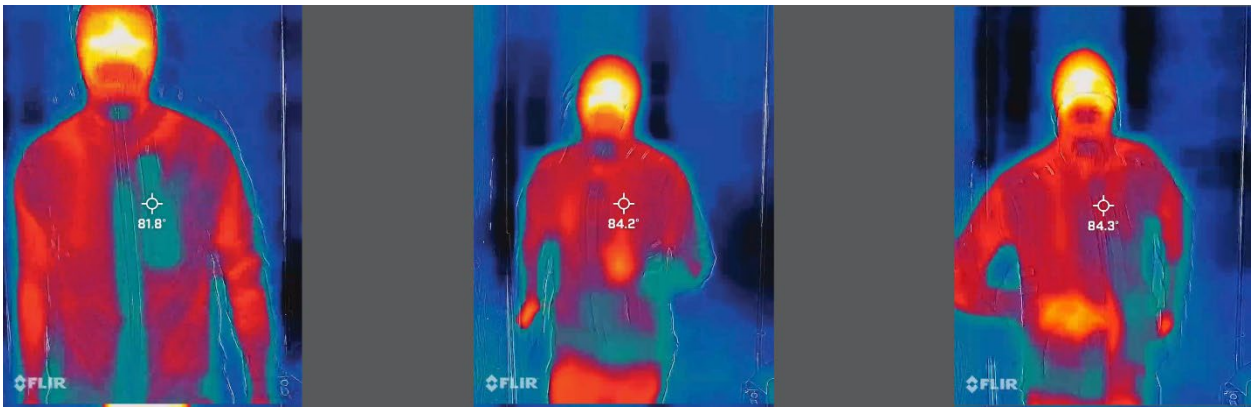


Figure 48 – Infrared Imaging of Prototype Pants, Jacket, and Beanie

The main takeaways are that when the prototype jacket was opened up, there was obvious heat release between the flaps of the front panels, but the camera view has only one angle so the heat being released around the sides is not being shown. There was obvious heat release from the top of the head as soon as the beanie was opened up.

4. Field Testing for Perceived Mobility, Comfort in Regard to Heat and Vapor Release, and Ability to Rapidly Cool Down

This testing was completed on the prototype jacket, pants, and beanie as described in the Performance Testing Plan section. The conditions were 51 degrees F, sunny with low winds. The following questions were asked after testing and answers recorded.

Do you feel the jacket allowed you to make all movements necessary to skate ski?
● **Yes** ○ **No**

While skate skiing, were there any places on the jacket that you feel could use more or less "give" to allow for better movements? If so, where?
○ **Yes** ● **No**

Do you feel the pants allowed you to make all movements necessary to skate ski?
● **Yes** ○ **No**

While skate skiing, were there any places on the pants that you feel could use more or less "give" to allow for better movements? If so, where?

○ **Yes** ● **No**

Were there any parts, seams, or fabric panels on the jacket that felt uncomfortable while skate skiing and if so, where?

○ **Yes** ● **No**

Were there any parts, seams, or fabric panels on the pants that felt uncomfortable while skate skiing and if so, where?

○ **Yes** ● **No**

Were there any parts, seams, or fabric panels on the beanie that felt uncomfortable while skate skiing and if so, where?

○ **Yes** ● **No**

Do you feel that the jacket, pants, and beanie offered adequate wind protection?

● **Yes** ○ **No**

Approximately how long were you skate skiing before you started to sweat?

Within 20 minutes

Did you ever become uncomfortably sweaty and if so, how long were you skate skiing before you noticed that feeling?

○ **Yes** ● **No**

Did you ever feel overheated while skate skiing in the jacket, pants, and beanie?

○ **Yes** ● **No** **Because I was able to unzip the sides and open the hat top.**

How did you feel once you opened the jacket and beanie?

It felt like instant air conditioning.

For the following questions, please rate the garments on a comfort scale from 1 to 5, with 1 being very uncomfortable and 5 being very comfortable.

While skate skiing, how comfortable did you feel wearing the jacket considering only your sweating experience and the ability of the garment to ventilate?

2

While skate skiing, how comfortable did you feel wearing the pants considering only your sweating experience and the ability of the garment to ventilate?

3

While skate skiing, how comfortable did you feel wearing the beanie considering only your sweating experience and the ability of the garment to ventilate?

3

How comfortable did you feel wearing the jacket considering only your ability to move in all positions necessary to skate ski?

4

How comfortable did you feel wearing the pants considering only your ability to move in all positions necessary to skate ski?

4

How comfortable did you feel overall wearing the jacket while skate skiing?

2

How comfortable did you feel overall wearing the pants while skate skiing?
4

How comfortable did you feel overall wearing the beanie while skate skiing?
3

Please rate your overall feeling of comfort using the jacket, pants and beanie in regard to wind protection.
4

Please rate your overall feeling of comfort using the jacket, pants and beanie in regard to their ability to allow all needed movements.
5

Please rate your overall feeling of comfort using the jacket, pants and beanie in regard to ventilation and heat release (passive cooling).
4

Please rate your overall feeling of comfort using the jacket, pants and beanie in regard to their ability to allow you to cool off (to prevent overheating).
5

Please rate your overall feeling of comfort using the jacket, pants and beanie.
5

The main takeaways were that the athlete rated the prototypes higher or equal to the benchmark products tested regarding wind protection, the allowance of needed movements, ventilation/passive cooling, overheating prevention, and overall comfort.

New Technology in Product Line

Three platform technologies are being introduced in this product line. Moov is targeted stretch within non-stretch wind-blocking panels. It is implemented following Langer's lines, which were explained in the Body Mapped Functional Zoning section.

Added stretch along Langer's Lines, the skin's stretch and fold lines

moov

Movement technology following natural stretch lines

Figure 49 – Moov Technology

The second platform technology, called Opn, is wearer-controlled, customizable airflow and heat release technology. A convertible beanie and jacket allow markedly increased airflow when wanted. These advancements allow for a quick cooldown to prevent overheating.

Figure 50 – Flo Technology

The third platform technology, called Flo, is superior passive heat release technology. Oversized, highly porous stretch mesh vents are incorporated into the upper back panel of the jacket and the back of the pants below the waistband. The waistband is also fully constructed of a two-layer elastic mesh. These allow for a massive release of vapor and heat.

Figure 51 – Flo Technology

Materials, Features, and Benefits

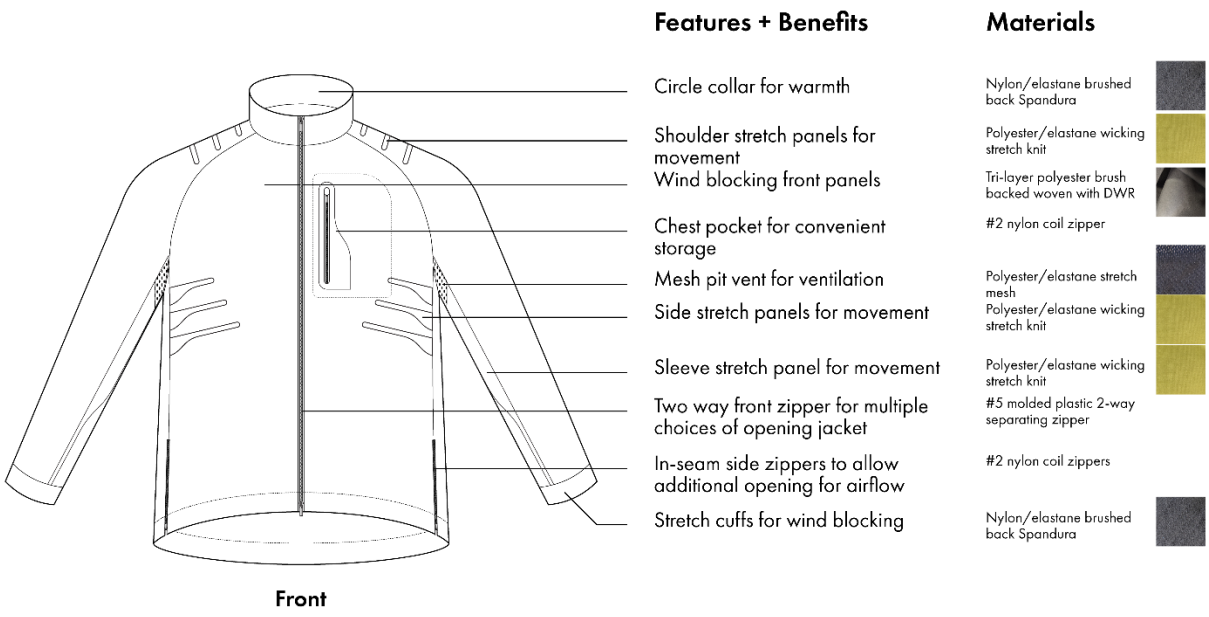
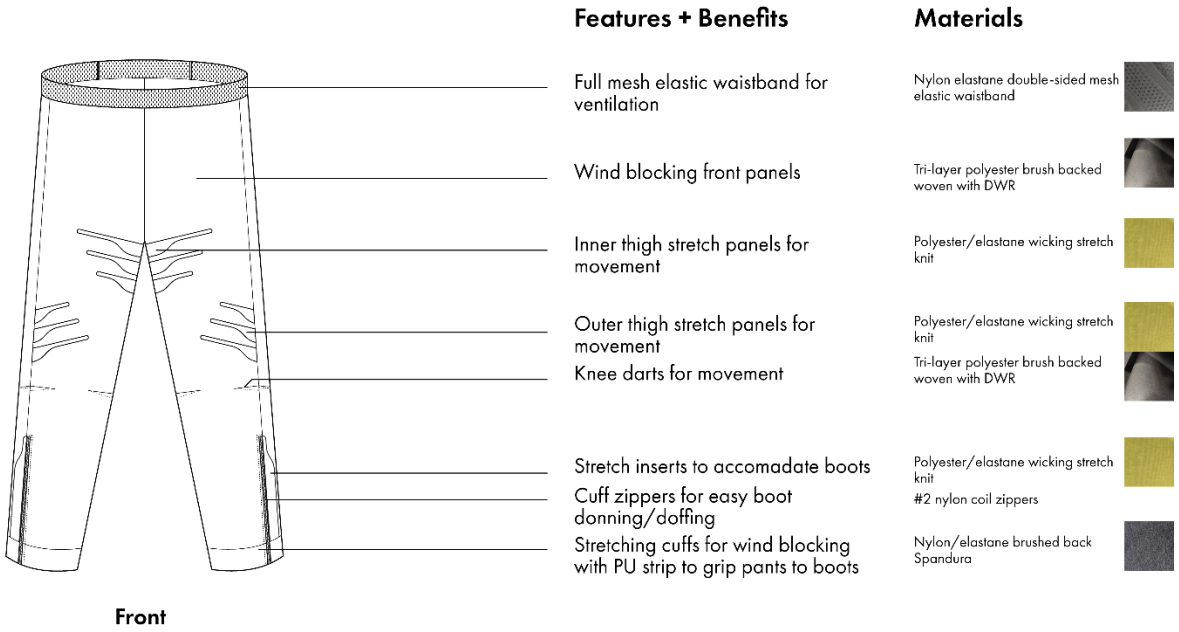


Figure 52 – Jacket Flats with Materials, Features, and Benefits



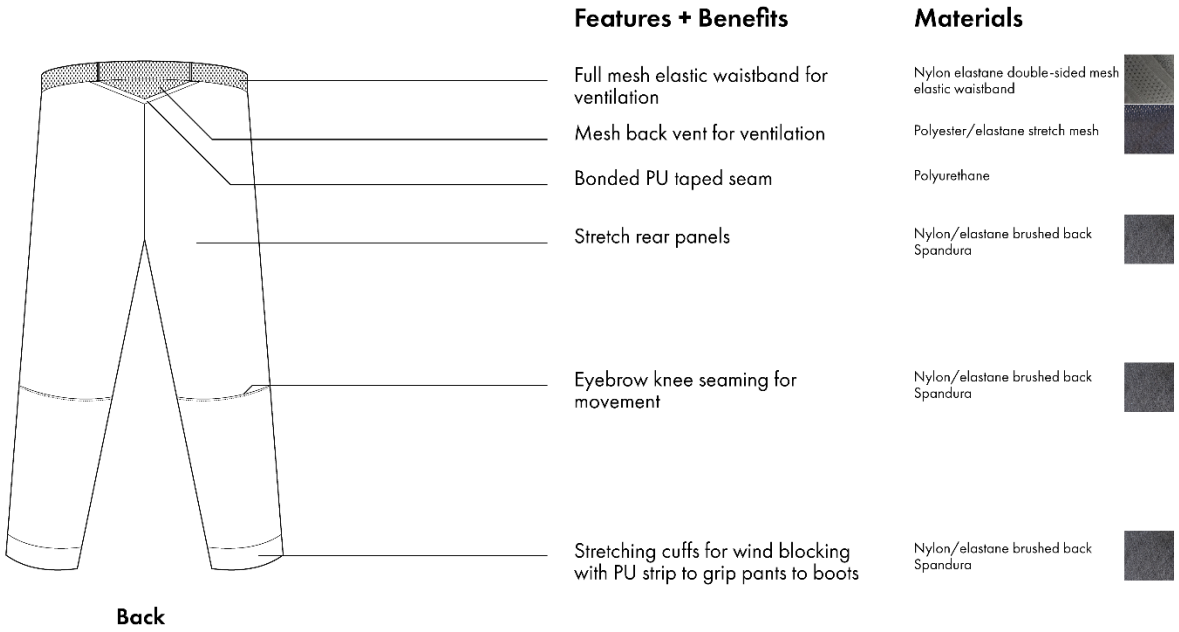


Figure 53 – Pants Flats with Materials, Features, and Benefits

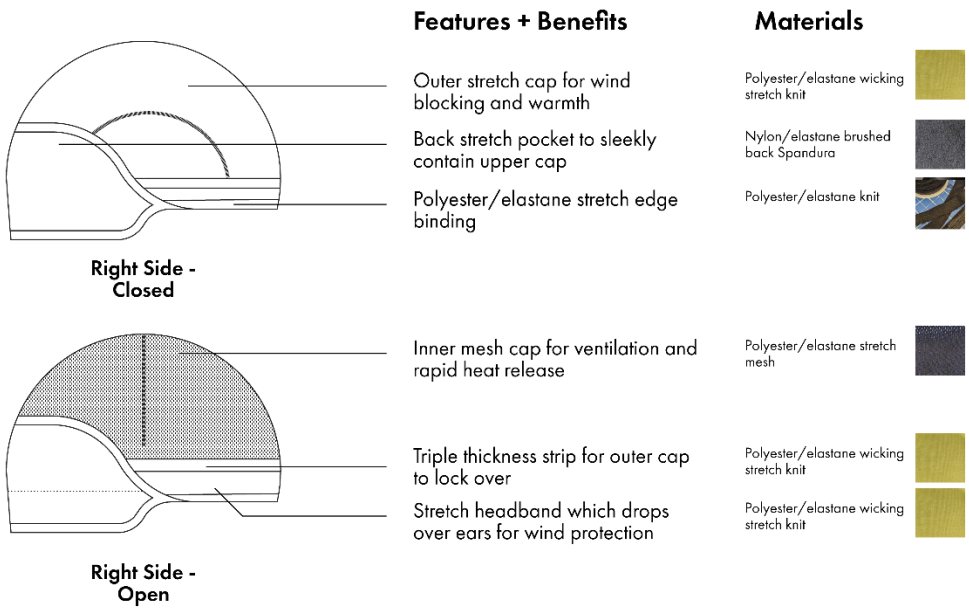


Figure 54 – Beanie Flats with Materials, Features, and Benefits

Aesthetic Direction – Mood Board and Color Palette

Figure 55 – Mood Board & Color Palette (Silva, 2013), (Hodgson, 2016), (Browning & Kostiak, 2022)

A mood board (Fig. 55) was created to convey a design direction which includes creative blocking, bonded elements, and close-body (but not skin-tight) silhouettes. The direction is heavily influenced by the colors and shapes of the aurora borealis, with multiple versions of elongated S-shaped curves. A palette of bright, aurora-inspired colors and muted greys with black was chosen.

Brand Name and Logo

The brand name for the collection is Skadi (Skaði), the Norse goddess of skiing and winter (Wikimedia, n.d.).

Skadi (Skaði) /SKAH-dee/- Norse goddess of skiing and winter

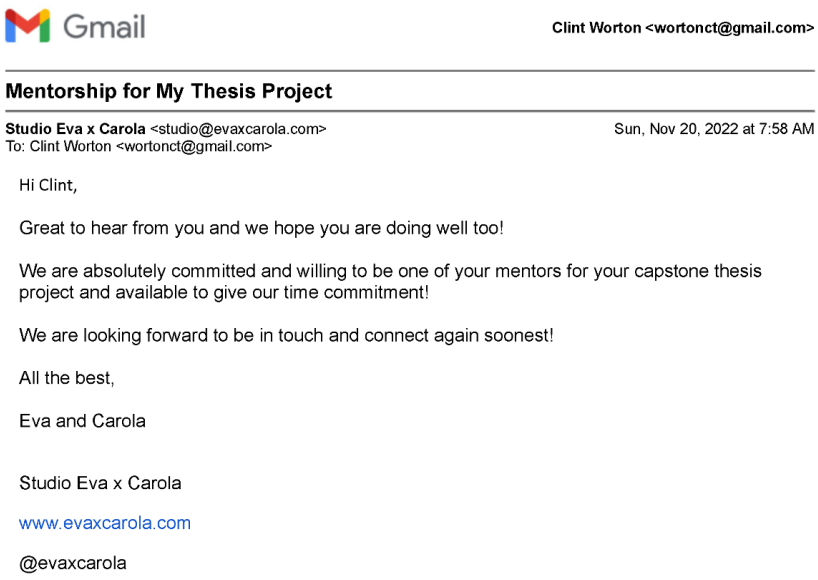
Figure 56 – Logo and Brand Name

Professional Interests, Personal Strengths, and the Golden Circle

My top five strengths according to my *Clifton Strengths Assessment* are futuristic, competition, deliberative, ideation and strategic (Rath, 2007). My futuristic and ideation strengths are vital in helping me create an innovative product line in this thesis project. My deliberative and strategic strengths will help me find the right paths to get all of the work done on a high level. In this project, my competition strength will help push me to create apparel that is better than what exists now. That directly leads into my golden circle statement, which is: I challenge the conventional by making unforeseen connections to create innovative sports products. This capstone project aligns perfectly with my future career goals. I want to be a technical apparel innovator, and this body of work will showcase that I have what it takes to do just that.

Mentors

My two mentors are Eva de Laat and Carola Leegwater, founders of Studio Eva x Carola, whose company focuses on seamless knitting innovation and the design of performance wear tailored to the athlete. They will be invaluable resources in my quest to innovate the baselayer and possibly the hat for skate skiing, but also, their vast experience in performance wear and understanding of manufacturing processes will be helpful as I innovate all of the garments in the line. The plan is to video meet with them in the first week of every month, for approximately an hour each time. They are also very willing to answer questions by email anytime.



Gmail — Clint Worton <wortonct@gmail.com>

Mentorship for My Thesis Project

Studio Eva x Carola <studio@evaxcarola.com> Sun, Nov 20, 2022 at 7:58 AM
To: Clint Worton <wortonct@gmail.com>

Hi Clint,

Great to hear from you and we hope you are doing well too!

We are absolutely committed and willing to be one of your mentors for your capstone thesis project and available to give our time commitment!

We are looking forward to be in touch and connect again soonest!

All the best,

Eva and Carola

Studio Eva x Carola

www.evaxcarola.com

@evaxcarola

Figure 57 - Confirmation Email From Mentors

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