EMBRACE: Hood to Coast Adaptive Athlete Training Collection

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Capstone Project 2024

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Hood to Coast is a challenging and memorable 197-mile relay race that takes place every year in Oregon. The relay race starts at the Timberline Lodge at Mount Hood and finishes at the Oregon coast city of Seaside. Athletes work in teams of twelve, with two vans to complete the race in a 24 to 36-hour range. In its 41-year history, the 2022 race was the first year that a mixed adaptive athlete team completed the race (Burka, 2022). The adaptive athlete team, So Every BODY Can Move, highlights the capabilities of different bodied athletes, and promoted awareness of their unique backgrounds.

History of Hood to Coast

The Hood to Coast Relay race began when Bob Foote, President of the Oregon Road Runners Club, sought to create a new running challenge. The first race, on August 7, 1982, featured 8 teams of 10 runners covering 165 miles from Timberline Lodge to Kiwanda Beach near Pacific City, Oregon, with the course marked every five miles. As the race grew in popularity, the need for more exchange points varied the course lengths. In 1989, organizers moved the finish line to Seaside, Oregon, increasing the race's total mileage and expanding teams to 12 members (History, 2023). The race now attracts a range of participants, from ultramarathon runners to non-competitive walkers. In 1990, organizers created the Portland to Coast Walk Relay for walking teams, now the world's largest walk relay. The race continued to grow, welcoming its first all-wheelchair team in 1993, and in 1994, elite runners set a course record. By 1998, the race included high school teams in the Portland to Coast Challenge Relay (Jensen, n.d).

The relay race fundraises significant amounts for charity and is a major economic driver for Oregon. Since 2013, the Providence Hood to Coast fundraising team has raised over $6 million for cancer research (Providence Hood to Coast Raises, n.d.). Hood to Coast Relay partners with World Vision to raise over $1 million annually for international charity missions (Partners, 2023). In 2003, the economic impact of Hood to Coast and Portland to Coast on Oregon was estimated at $26 million annually (History,

2023). Today, Hood to Coast is the world's largest run and walk relay, with over 1,000 teams, 20,000 runners, 3,600 volunteers, and a 40,000-person waitlist (Minsberg, 2022). Its international events in China, Taiwan, Israel, and Hainan further highlight its global appeal, economic impact, and charitable contributions.

User Focus: Adaptive Athlete

According to Hood to Coast COO Dan Floyd, of the estimated 20,000 participants, only 1% are athletes with disabilities (Burtka, 2022). My project is focused on the needs of amputee athletes who require the use of prosthetic running blades on the So Every BODY Can Move team. The team's members have physical disabilities, including amputations and limb differences, and vary in age from 20 to 40, with diverse ethnic backgrounds.

The 2023 team consists of founder, triathlete, and amputee Nicole Ver Kiulen, Patrick Pressgrove, SaraMae Hollandsworth, Leah Kaplan, Erica Korpi, Kionte Storey, Kyle Stepp, Amelia Dittmar-Maggs, Kelsey LeFevour, John-Edward Heath, Dee Palagi, and Robert Anthony (Meet the Team, n.d.). Most of these athletes were either born with their disability or acquired it later in life. For instance, Nicole lost her leg to bone cancer at age 10, and SaraMae lost both her legs to a life-threatening infection 10 years ago. SaraMae grew up running Hood to Coast two decades ago in high school before the loss of her legs (KGW8, 2023).

The team has a mix of men and women with various athletic backgrounds. In 2018, Nicole completed a 1,500-mile triathlon along the West Coast of the United States. Patrick Pressgrove, a double above-the-knee amputee, is an accomplished endurance athlete who has completed multiple marathons, the Boston Marathon, and half Ironman triathlons (Rowe, 2022). Amelia Dittmar-Maggs, who lives with a below-knee limb loss, found Hood to Coast her “first official time doing anything athletic in an event” (Markwardt, 2023). Despite their diverse athletic backgrounds and disabilities, the So Every BODY Can Move team has overcome many adversities to participate in the Hood to Coast relay race.

Performance Problems

Adaptive athletes on the So Every BODY Can Move, encounter a range of performance-related challenges that are tied to the design and functionality of their specific gear. My project is focused on the performance issues of leggings, and prosthetic blade outsoles. To address these issues and enhance their overall performance, several improvements can be made.

Prosthetic-specific apparel must accomodate the amputation, ensuring a comfortable fit for athletes during their training and races. In particular, leggings should wick away sweat and moisture to keep the skin dry during physical activity. Furthermore, graduated compression leggings can enhance blood circulation, provide support, and reduce muscle fatigue for their residual limb (Compression Clothing, 2022). Finally, prosthetic apparel for transtibial amputees must enable the regular transition from their walking leg to their running leg in order to run. For the transtibial athlete, apparel designed for able bodied athlete can hamper their efforts to exercise and train. The transtibial athlete faces a cumbersome process of changing from their walking leg to their running leg, and involves rolling and unrolling the excess legging material or requires the cutting of their leggings (Figure 1).

Figure 1: Athlete Donning and Doffing Prosthetic Legs

Lastly, the development of a durable mixed outsole for racing prosthetic blades is neccessary. This solution could be interchangeable, enabling athletes to seamlessly transition between various terrains, including roads, trails, and sand, optimizing their

performance across diverse race conditions. Currently on the market the blade outsoles are made for road running without the quick option to interchange soles (Trail Blader, n.d.). For adaptive athletes this would require the costly addition of specific prosthetic blades per course condition (Road Ready:Nike Sole 2.0, 2021). Furthermore, adaptive athletes may have physical impairments that making doning and doffing equipment and apparel difficult. It is essential that interchangeable outsoles be easy to install and remove onto their running blade.These improvements are essential in providing adaptive athletes with the footwear, and apparel they need to reach their full potential and excel in the Hood to Coast Relay.

Sport Environment

The Hood to Coast Relay race is challenging due to its variable course, evening running, and weather conditions (Hood to Coast, 2023). The 197-mile course starts at Mount Hood at 6,000 feet of elevation, runs through Portland, and ends at Seaside beach (Figure 2). The significant elevation changes require a range of skills and physical adaptations. The race occurs continuously, including through the night, with most teams finishing in about 29 hours (Hood to Coast, 2023). Nighttime running introduces obstacles like reduced visibility, fatigue, and the need for proper lighting (Hood to Coast, 2023).

Athletes must also contend with temperatures ranging from 40 degrees at night to over 90 degrees during the August daytime (Markwardt, 2023). Certain race legs lack shade, leading to risks of sunburn and dehydration (Figure 3). Athletes need protective measures like sunscreen, appropriate clothing, and effective hydration strategies. In conclusion, the Hood to Coast Relay is a formidable test of endurance, requiring athletes to overcome variable terrain, significant elevation changes, continuous nighttime running, and changing weather conditions.

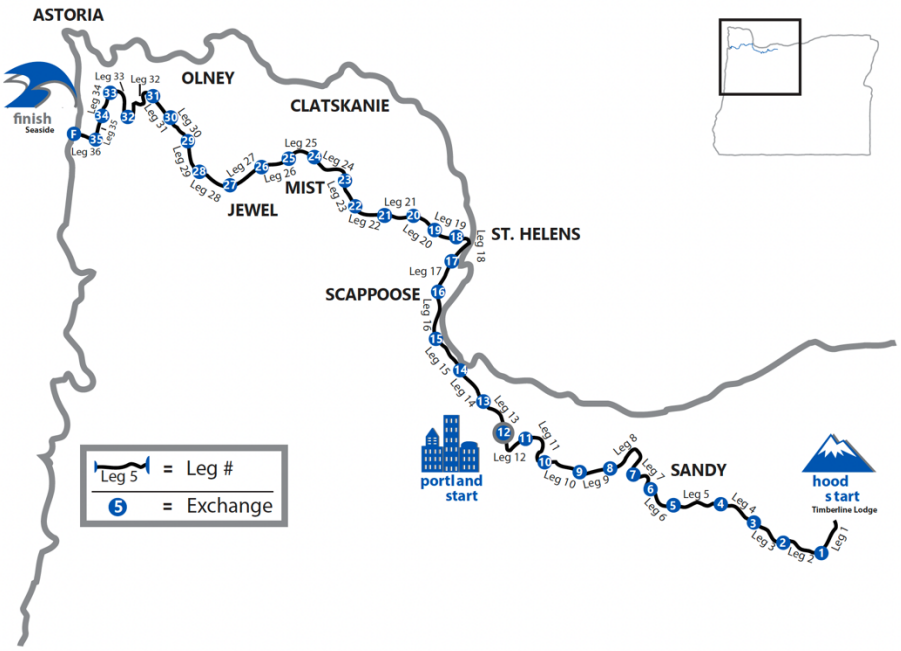


Figure 2: Race Course (Hood to Coast, 2023)

= Little/No Shade = Quiet Zone E = Easy H = Hard
= Considerable Elevation Gain/Loss = Gravel (possible dust) M = Moderate VH = Very Hard

		1st Leg			2nd Leg			3rd Leg			Totals/Rankings			
Van	Runner	Leg # / Remark	Mileage	Rating	Leg # / Remark	Mileage	Rating	Leg # / Remark	Mileage	Rating	Total Miles	Mileage Ranking	Relative Difficulty	Difficulty Ranking
Van 1	1	1	5.44	VH	13	5.21	E	25	3.80	E	14.45	12	16.08	11
Van 1	2	2	5.64	H	14	6.04	M	26	5.65	H	17.33	4	20.19	4
Van 1	3	3	4.66	E	15	7.25	H	27	6.36	M	18.27	1	20.36	3
Van 1	4	4	7.18	M	16	3.92	E	28	3.83	E	14.93	11	15.65	12
Van 1	5	5	6.05	VH	17	5.32	M	29	5.97	VH	17.34	3	21.47	1
Van 1	6	6	7.10	H	18	4.13	H	30	5.32	M	16.55	5	19.32	5
Van 2	7	7	5.25	M	19	5.89	VH	31	3.96	M	15.10	10	17.49	9
Van 2	8	8	6.00	E	20	5.75	VH	32	4.20	M	15.95	8	18.09	7
Van 2	9	9	5.38	M	21	5.06	M	33	7.72	H	18.16	2	20.75	2
Van 2	10	10	5.54	M	22	6.70	H	34	4.12	E	16.36	6	18.25	6
Van 2	11	11	5.00	E	23	4.23	E	35	7.07	H	16.30	7	17.71	8
Van 2	12	12	5.85	M	24	4.87	E	36	5.03	M	15.75	9	16.83	10

Figure 3: Course Leg Breakdown (Hood to Coast, 2023)

Potential Market

While the representation of adaptive athletes is less than able bodied athletes, persons with disabilities account for a significant amount of the world's population. For example, according to the World Health Organization, compared to the world's 7.888 billion population approximately 1.3 billion people or 16% has some form of disability. Globally this statistic represents 1 in 6 (Disability, 2023). For the United States the

percentage numbers are even higher. According to the Center for Disease Control, 1 in 4 adults or 27% of the domestic population have some type of disability. Of those impacted, 12.1% have a mobility disability, 6.1% are hearing impaired, and 4.8% experience vision difficulty (Disability Impacts All of Us, 2023).

Finally, it is projected that the adaptive clothing market is an untapped market segment with high projections for growth. In fact, according to Coresight Research the global adaptive apparel market would have reached $288.7 billion in 2019 and have grown to $349.9 billion in 2023. Their research expects the United States to account for $54.8 billion of that growth (The US Adaptive Clothing, 2019). Considering the significant domestic and global populations of people living with some form of disability, and its untapped potential it is important to design new sports products to address this market need.

Athlete's Jobs to Be Done

Participation in the 197-mile Hood to Coast race requires extensive physiological and thermoregulation demands. Physiological demands include adequate hydration, proper nutrition, fatigue management, and injury prevention. Without proper hydration, athletes risk dehydration, overheating, and decreased muscle performance (Sawka et al., 2007). Maintaining adequate nutrition, especially carbohydrate and protein intake, is crucial for energy and muscle recovery (Hiscock, 2014). Athletes must pace themselves and rest between legs to manage fatigue and prevent overuse injuries and slips.

Thermoregulation demands arise from the race's varying temperatures. Athletes face cooling, warming, and moisture management challenges as they transition from cooler mountainous terrains to warmer coastal areas. Effective cooling strategies are needed for sun-exposed segments, while layering is essential to conserve heat at night. Managing sweat accumulation is crucial to prevent chafing, blisters, and discomfort. Adaptability and careful planning are key to overcoming these conditions and achieving peak performance.

Competition Rules

According to the official Hood to Coast guidebook, the required gear includes the athlete's race number and safety reflective gear for nighttime running. For the safety of all the athletes, they must wear their race bibs for identification and have their emergency contact information on the back of the bib. The large number of participants inevitably results in unforeseen injuries, and it is critical that emergency providers be able to respond in a timely manner. An additional product rule is in terms of safety gear, "from 6:00pm to 7:00am all participants must wear one front and back LED flasher, carry a flashlight, wear a headlamp, or wear a head headlight, and wear a reflective vest through 9:00am (Hood to Coast, 2023, p.20). Participants will not be able to continue through a leg handoff without the proper safety gear. These product rules are essential for the safety of the many Hood to Coast race participants.

Product Classifications

For prosthetic adaptive athletes, gear choice is critical for success. These athletes face unique challenges and need specialized apparel and footwear tailored to their needs. My project focuses on two blade outsoles—one for trails, one for sand—and adaptive leggings (Figure 4). The goal is to improve the don and doff times of the athlete's prosthetic walking leg to their running leg and design durable outsoles for sand and gravel conditions.

Proper training and race day apparel are essential, providing features like moisture-wicking to prevent chafing and compression to enhance performance. It also allows easy donning and doffing of the prosthetic leg (Comprehensive guide to prosthetic leg running, n.d.). Specialized blade outsoles offer stability, support, and traction, especially for athletes with mobility limitations. The right selection of apparel and footwear enables adaptive athletes to overcome physical limitations and excel in their sport.

Figure 4: Product Collection

Design Project Statement

Considering the physical and gear challenges for the Hood to Coast unilateral transtibial athlete, how could we create interchangeable prosthetic blade outsoles and adaptive legging bottoms to improve unilateral transtibial athlete don and doff times and traction, while also celebrating their unique experience in the Hood to Coast Race?

Golden Circle Statement

Why: Empower adaptive athletes to realize their fullest potential while fostering a sense of belonging and acceptance.

How: By implementing innovative and user-centered focused designs that celebrate their unique experience.

What: Promote inclusivity of diverse athletes by addressing their specific sport needs.

Product's Job to Be Done

Each product in the design collection serves a crucial purpose. The leggings must excel in fit and comfort, secure closure, and prosthetic compatibility. Ensuring a proper fit that accommodates the amputation without causing discomfort is key. The

fabric should be moisture-wicking, and seam construction should provide support and flexibility. The leggings should also have a secure closure of the thigh hem and leg sleeve, staying in place during movement, and should be prosthetic compatible by accommodating the prosthetic socket without interfering with the liner.

For prosthetic blade outsoles, the critical jobs include providing superior traction for stability and grip, and enabling ergonomic fast donning and doffing times. Superior traction is crucial, especially on loose surfaces like gravel and sand. Athletes also need balance, stability, and propulsion support, with grip essential for generating forward propulsion and efficient push-off during running. The blade outsoles should have ergonomic removal, allowing athletes to swap outsoles quickly and easily for different surface conditions, such as those in the Hood to Coast race. Fulfilling these jobs effectively can significantly improve the overall user experience for transtibial athletes.

Market Legging Competitors

In the market for amputee leggings, Lululemon's Fast and Free High Rise leggings stand out for their lightweight and sleek nylon and elastane Nulux fabric, priced at $128. They feature a comfortable drawcord waistband, a cool feel next to the skin, and five pockets for running essentials. The leggings are also patterned with no inseam to reduce chafing and irritation from additional seams.

Nike's Go Women’s Firm Support High-Waisted 7/8 leggings, priced at $110, offer a compressive and supportive fit with a midweight 68% nylon and 32% InfinaLock fabric. They feature an extra-wide waistband for comfort, six pockets, moisture-wicking Dri-FIT technology, and an internal drawcord to adjust the waist. (Nike Go Women’s Firm Support, n.d.).

Curves N Combatboots Amputee Leggings, priced at $60, are designed specifically for prosthetic athletes. Available in leg-specific amputation designs, they are patterned to be shorter for the residual limb. The leggings have two side pockets and a polyester and spandex blend fabric. Sales profits support the Kirstie Ennis Foundation, dedicated to helping amputee athletes with outdoor recreational therapy. (Amputee Leggings with Pockets, n.d).

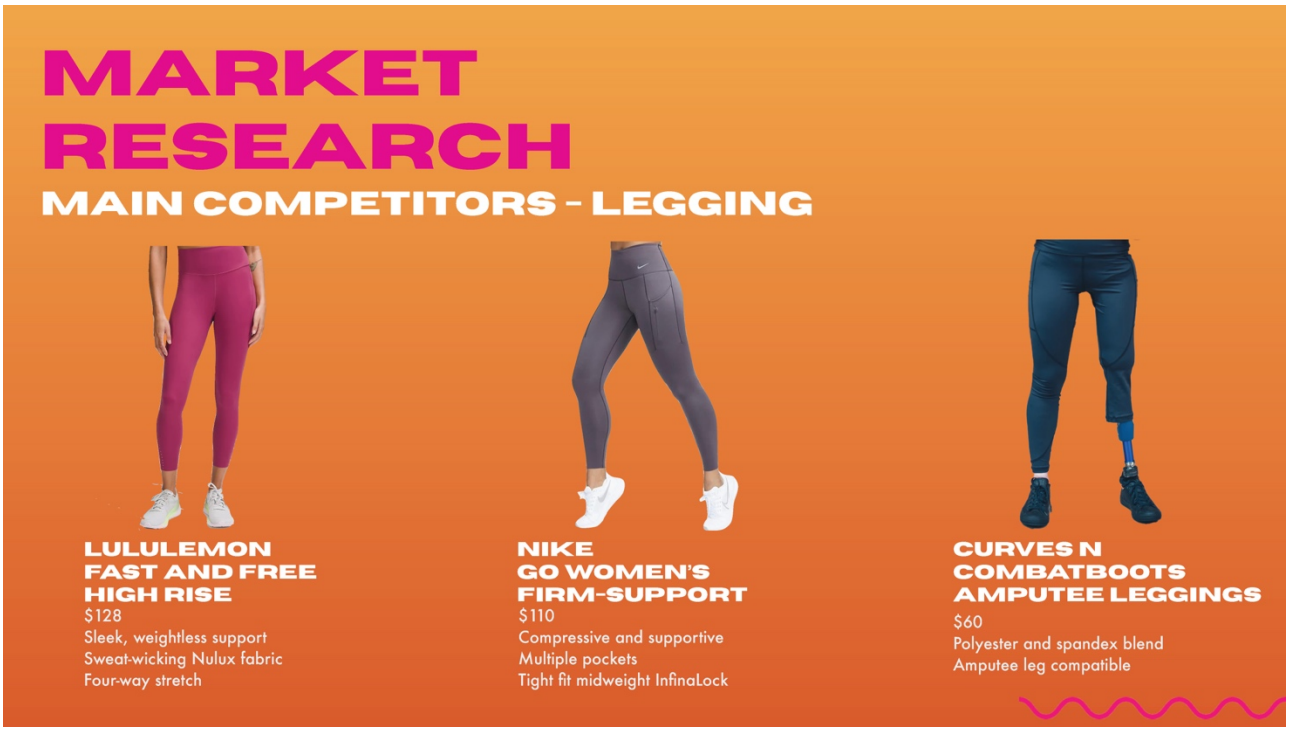


Figure 5. Legging Market Competitors

Legging Construction + State-of-the-Art Material

Leggings are typically made from stretchy fabrics like nylon, polyester, or spandex for a snug and comfortable fit. Key components include the waistband, body, gusset, seams, and hems (Miranda, 2018). Waistbands are usually elasticized or feature a drawcord to prevent slipping. The body is seamless or has strategically placed seams to enhance comfort and minimize chafing. A gusset, often a triangular or diamond-shaped panel, is sewn into the crotch to allow better range of motion and reduce stress on seams. Seams are flatlock or cover-stitched to prevent skin irritation. Hems may have thermal bonding to keep the fabric in place and prevent rolling during movement. Additional features may include pockets, mesh panels for breathability, or compression zones for support and muscle recovery. State-of-the-art leggings use computerized circular knitting machines to create seamless designs, reducing friction and irritation. Merino wool, known for being breathable, elastic, and odor-resistant, is a promising material for technical seamless performance apparel (The latest Merino Yoga Collection Goes Seam Free, 2020).

Figure 6. Legging Construction

Legging Manufacturing

The manufacturing of an adaptive legging follows similar process of typical apparel manufacturing. The process entails pattern making which is usually done on a computer software. Next a pattern is cut using a computerized cutting machine for precision. The machine can cut through multiple layers of fabric at once, which reduces fabric waste (Newcomb, 2019). Then the pattern pieces are assembled, sewn together, or sealed depending on the design. Finally, the leggings hardware and trims such as zippers and closures are attached to the finalized legging.

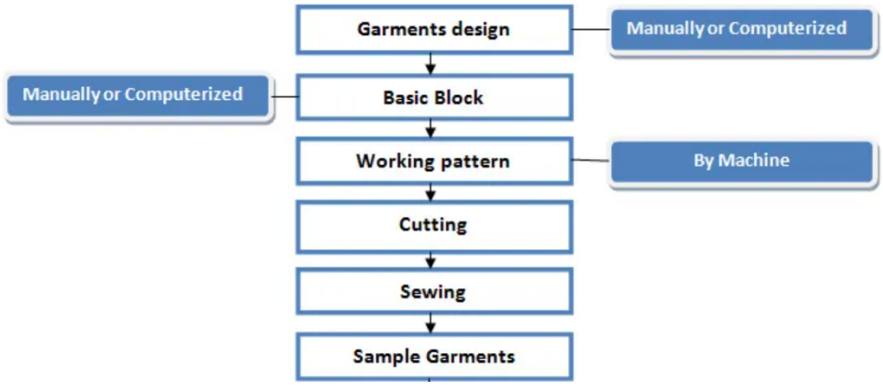


Figure 7. Flow Chart of Garments Sample Making (Shaikat, 2020)

Prosthetic Blade Competitors

In respect to prosthetic blade outsoles, one the state-of-the-art products is the Nike x Ossur flex-run foot. The design features a longer toe lever and efficient energy return. Combined with a Nike design outsole, it offers great traction and energy return to help improve running efficiency. Its finger like carrier tabs ease the installation. The outsole is sold for $193 (Ossur. Life without limitations, n.d.).

Figure 8. Blade Outsoles Market Competitors

At a more affordable price point is the Levitate Gravel Sole that is sold for $100. The Levitate features a direct-injected TPU outsole and PU single plastic components making this design both durable and less expensive. The design features a robust traction design, and a single component design that only requires two screws for installation to a prosthetic blade.

Finally, the Ottobock sole kit 2Z500 fitness sole is sold for $300. The outsole is especially designed to outfit the Ottobock 1E90 sprinter foot. The sole is designed with a universal sole and running shoe tread is suitable for mixed use surfaces. The outsole can also be swapped out for a sole with spikes designed for track use.

Product Construction + State-of-Art Material

The anatomy of the Nike x Össur state-of-the-art outsole is a well-engineered construction that optimizes performance and comfort. At its core, the Carrier Tabs and Attachment System act as robust fingers around the blade, ensuring secure attachment and stability. The Moderator/Interface, crafted from TPU plastic, plays a crucial role in providing exceptional grip between the blade and sole, enhancing traction and control. To enhance comfort, the midsole incorporates PU foam, offering cushioning that absorbs impact and minimizes strain during activity. Finally, the outsoles are designed with a durable rubber waffle pattern, delivering superior traction on a variety of surfaces, making these shoes a perfect choice for those seeking improved performance (Filipetti, 2015). In terms of a high-performance foam for the outsole, PEBAX provides the most energy return for its weight. PEBAX which is a type of thermoplastic (TPE) foam has a higher density than TPU and EVA making it more durable and rigid.

Figure 8. Nike x Össur Product Anatomy

Product Manufacturing

The manufacturing process of a prosthetic blade outsole begins with the creation of a mold designed using CAD software. This mold is typically made of metal and

serves as the foundation for shaping the outsole. Following the mold's preparation, layers of composite material, such as carbon fiber or EVA, are meticulously placed into it. Once the composite layers are in position, a combination of high temperatures and pressure is applied to facilitate the curing process, ensuring the material hardens and adheres to the desired shape (Barrios-Muriel et al., 2020) After curing, the outsole is carefully trimmed, and any rough edges are smoothed down. It is then assembled with other soles components to form the complete prosthetic blade outsoles.

Competitor SWOT Analysis

Competitors in the adaptive training leggings market include Nike Go Women's Firm Support and Curves N Boots Amputee Leggings. Nike's leggings excel in firm fit compression for muscle support, while Curves N Boots offers a prosthetic-compatible design, available in various options for right, left, above, or below knee amputations (Amputee Leggings with pockets, n.d.). Nike's leggings feature six pockets and one zippered pocket (Figure 9). However, Curves N Boots' design is limited to amputee leg-specific options, lacking inclusivity for a wider range of adaptive athletes.

To improve, a modular prosthetic-compatible training legging could be designed, potentially using magnets or anti-slip silicon to accommodate various prosthetic athletes regardless of their specific leg amputation. However, adding trims, hardware, and a more complex pattern could increase seams and chafing. Additionally, sourcing suitable trims and premium fabric may increase the final product's cost, potentially making it prohibitive for some athletes.

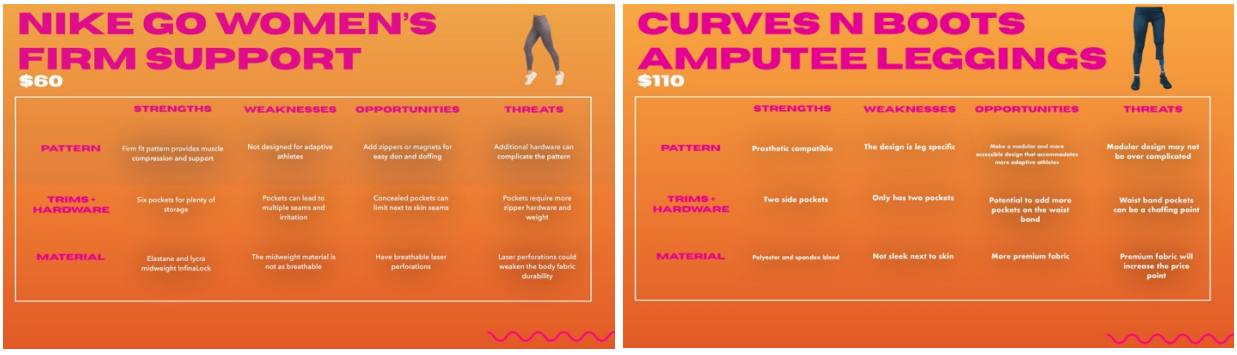


Figure 9: Training Leggings

Competitors in the prosthetic blade outsoles market include Nike x Ossur and Levitate. Both excel in outsole traction, with Nike x Ossur designed for pavement

surfaces and Levitate for trails. They share an attachment design for easy installation, with Levitate requiring only two screws (Figure 10). However, Levitate's two-screw system may not be secure over time, risking screw thread wear with repeated use. Its design is less adaptable for different surfaces. In contrast, Nike x Ossur's four-layer system and "finger"-like attachment style are complex and expensive to manufacture, with potential for more failure points.

To improve, a simplified design using 3D printed components could enhance manufacturing ease and attachment designs. Creating a traction outsole for both trail and pavement surfaces with new rubber composites could benefit both Levitate and Nike x Ossur. However, 3D printed components may lack structural strength, requiring rigorous testing. Athletes may also prefer Levitate's simplified attachment design over a more complex system. Overall, there are various strengths, weaknesses, opportunities, and threats for Nike x Ossur and Levitate prosthetic outsoles.

Figure 10: Prosthetic Blade Outsoles

Intellectual Property Landscape

The intellectual property landscape of adaptive related products is extensive. For prosthetic blades, patent US2020085597A1 is a clip attachment with a channel surface for easy installation (Greene et al., 2019). Bridgestone has half a dozen prosthetic blade sole traction patents including US20210290413A1 (Itoi et al., 2019), US20210275328A1 (Itoi et al., 2019), US20210161684A1(Itoi et al., 2019). Their design involves different rubber traction patterns with gradual thickness. Finally, while there are no patents for adaptive leggings there are several patents for different ornamental USD774731S1 (Harris et al., 2015) and bandage designs USD875351S1(Harris et al., 2018) for

leggings. It is important to keep these patents in mind when designing the final collection to ensure no copyright infringement.

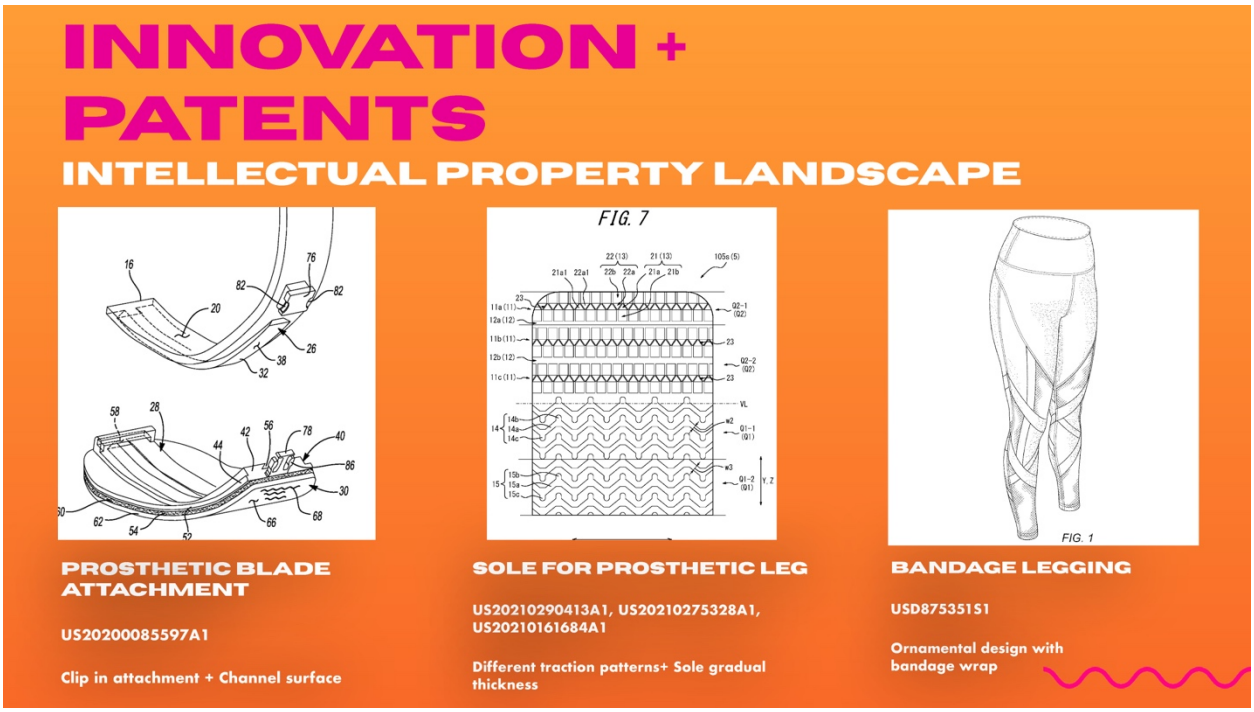


Figure 11. Intellectual Property Landscape

State-of-the-Art Trends

The state-of-the-art trends in adaptive sports equipment has seen little changing trends in regards to color, graphics, and logos. For running outsoles, the emphasis lies in functionality. These outsoles feature efficient minimalist designs with limited expressive colors and features. The prosthetic outsoles tend to be mostly neutral black with pops of contrasting colors. The adaptive leggings, on the other hand, tend to favor neutral and understated colors, such as black or olive green. Overall, graphics and logos have been reduced to a minimum. There are some exceptions such as the Nike logo on the bottom sole of the Nike x Ossur flex-run foot, but these are the exceptions and they do not follow a similar design language. These few trend outliers in the adaptive market reflect the desire to provide adaptive athletes stylish and functional sports product.

Figure 12. Today Trends

Future Color Trends

The latest color trends for autumn/winter 2025/2026, according to WGSN, feature a blend of electrifying contrasts and grounded, nature-inspired palettes. The "Neon Flare" trend combines neon cyber brights, signifying strength and exuding a futuristic, energetic vibe (McCarthy, 2023). These bold, eye-catching shades demand attention and express a dynamic sense of confidence. In contrast, warm color tones evoke comfort and tranquility, with earthy greens, serene blues, and warm browns connecting us to nature. "Earthen Mid-Tones," inspired by caramel's rustic charm, create a timeless, cozy atmosphere. Vibrant orange and deep indigo blue add unexpected pops of excitement, making spaces feel inviting and lively (McCarthy, 2023). These trends are important for designing adaptive apparel for Hood to Coast athletes.

Figure 13. Future Color Trends Color A/W 25/26

Future Graphic Trends

The latest graphics and key prints for outdoor and sport design for spring and summer 2025 include the “Shape Shifter” style. This design combines nostalgia inspired by the '90s, joyful geometric transformations, and ombre gradients (Chow, et al., 2023). In contrast, the "Outdoor Play" trend adopts a charming cartoon aesthetic that personifies nature. This graphic trend promotes a cheerful relationship between humanity and nature, with pastel camouflage patterns serving as a metaphor for our connection with the outdoors. While the adaptive space does not currently utilize graphics and trends it could be incorporated into the project with a travel bag for their prosthetic outsoles, or legging graphics. In conclusion, these trends collectively capture the essence of joy, nostalgia, and nature in the ever-evolving world of graphic design.

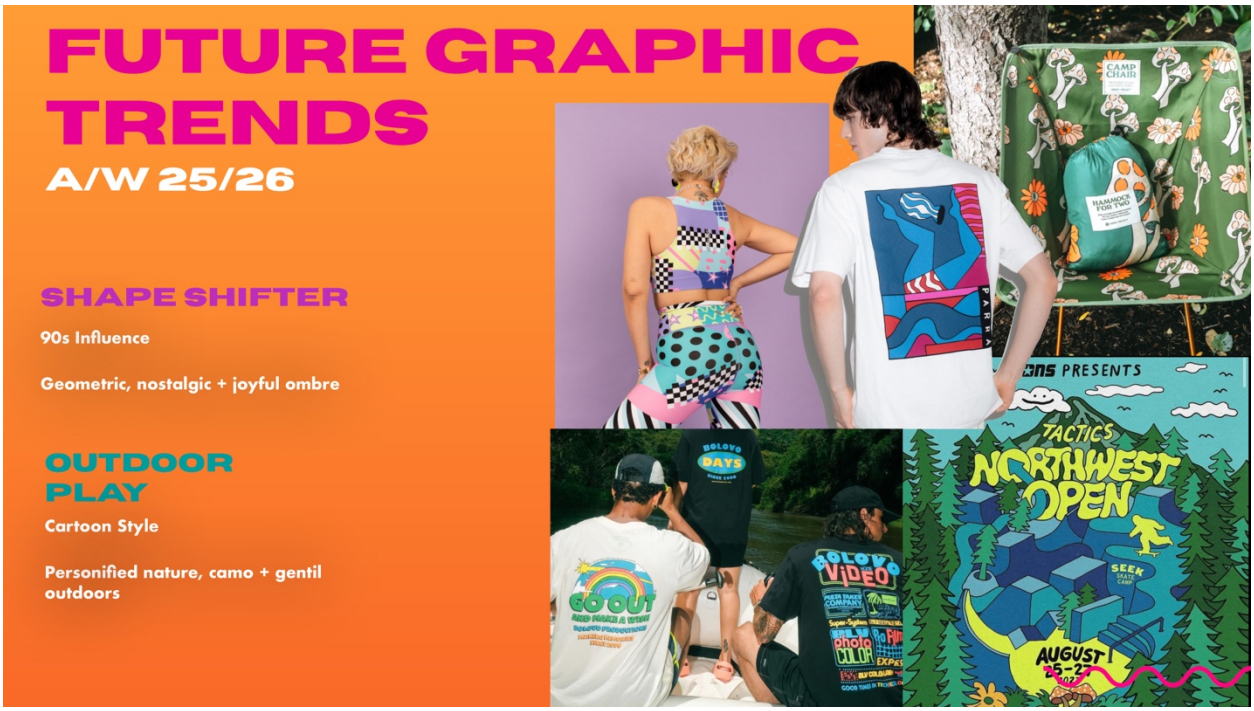


Figure 14. Future Graphic Trends

Collection Branding

The Embrace logo was created to highlight the peaks and valleys that the adaptive athlete had to overcome the Hood to Coast race, with a sense of optimism for an upward and excelling future. The final logo was located in the center of the tank to highlight the team aspect of the race, while being prominent to show pride in the unique adaptive athlete experience. The logo on the outsole was located at points of interaction such as the tab lock down and the bottom of the sole to draw attention when passing other runners. (Figure 15). These branding considerations enhance communication and visibility, fostering deeper connections with the adaptive athlete runner.

Figure 15. Collection Branding

Empathy Research

The experience of adaptive athletes highlights the interplay between physicality and identity, emphasizing the value of challenging stereotypes, self-acceptance, and individuality. These athletes often navigate a journey of self-discovery, where embracing their unique capabilities fosters a deep sense of self-acceptance. For Jacky Hunt-Broersma an adaptive athlete who completed 104 marathons in 104 days in 2020, she said, “Running really changed my life and it gave me a more sense of acceptance of my body” (Lewis, 2022). This journey challenges stereotypes that tend to oversimplify their experiences, portraying them either as tragic victims or as noble inspirations (Young, 2014). Instead, adaptive athletes advocate for recognition of their individuality, showcasing their diverse skills and personal strengths (Figure 16). Their stories challenge stereotypes, urging society to view them with understanding and respect instead of pity or undue adulation.

Figure 16. Empathy Research

Psychological Research

The Hood to Coast race provides many physical as well as psychological challenges for the athletes. Athletes will have to endure the pain, fatigue, and discomfort of running many miles, in the cold or heat, while experiencing sleep deprivation. During the race it is common that athletes will encounter unexpected setbacks. Part of their mental resilience will be tested by their capability to adapt to those challenges. An optimistic mindset will help them endure the hardship and push their bodies to new limits. Studies have shown that a positive mindset is correlated with better athletic performance (Gabana, 2019).

Last, the Hood to Coast athletes may have to overcome self-doubt. For adaptive athlete Amelia Maggs-Dittmar, Hood to Coast was her first time doing an official athletic event (Markwardt, 2023). She may have less confidence in her ability to complete the course. Finally, unfortunately some team members experienced name calling and dismissive remarks during the race from other participants (Markwardt, 2023). For the Hood to Coast adaptive transtibial athlete to succeed they will need to overcome mental and psychological challenges.

Physiological Research

During the Hood to Coast race, all athletes will undergo physical stress to their body, taxing both their cardiovascular and muscular systems. For their cardiovascular system, running will affect their body by increasing their heart rate, blood, and oxygen to the affected muscles. Furthermore, athletes will experience increased blood pressure as more blood will be redistributed to the muscles (Joyner et al., 2015). For athletes using prosthetic limbs, special coordination of residual limb muscles is essential to maintain balance. Finally, for amputee athletes' special consideration must be made to sweat and chafing, Adaptive athletes sweat more because part of their prosthesis is covered restricting evaporation. Also, they sweat more because they have less body surface to sweat and cool off (Why do Amputees Sweat More, 2021). For these reasons, it is essential to manage sweat and friction as they can lead to skin irritation, discomfort, and blisters. Adaptive athletes use multiple products such as sock liners, socket padding, anti-chafing, anti-sweat, lubricants and sweat towels to manage their prosthetic health when running (Potok, 2019). If left untreated athletes run the risk of infection and damaging their skin integrity.

Biomechanics Research Amputee

There are several biomechanical factors to consider when designing for amputee adaptive athletes. First, it is important to consider the prosthetic design. Each prosthetic is tuned to provide optimal flexibility and energy storage needed for each push off. The prosthetic blades were designed to closely mimic the human calf muscle and Achilles tendon (Potok, 2019). During running, the prosthetic blade is responsive in its energy return. During the stance phase, when the foot is in contact with the ground, the blade compresses to store energy. In the swing phase, the stored energy in the blade is released and it propels the athlete forward. Proper tuning of the blade is important that it is stiff enough to propel the athlete but still provide impact force reduction (Mareshamani, 2018). Ultimately, when running the amputee athlete must rely more on their upper body for balance (Rajťúková et al., 2014). They must utilize their core and upper body muscles to maintain upright posture and stability when running. It is clear

that amputee athletes undergo several biomechanical factors when competing in racing events.

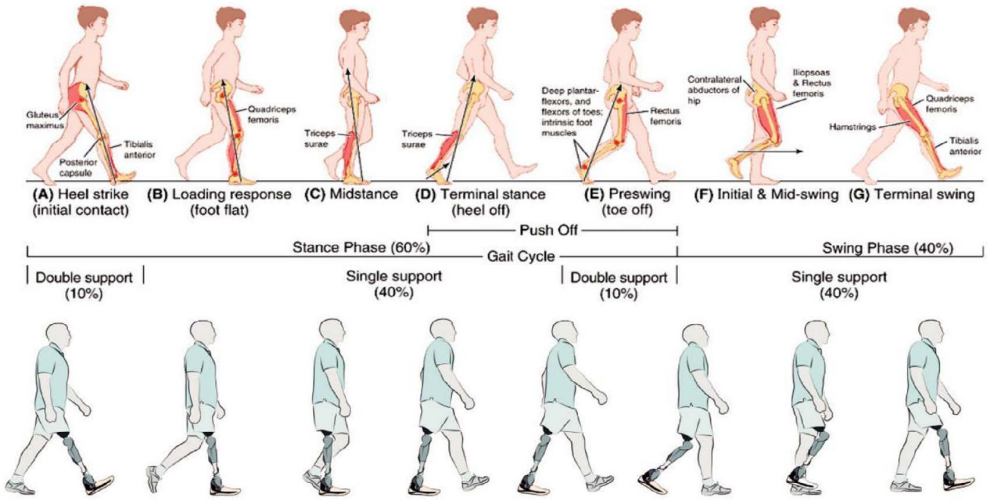


Figure 17: Running Stance of Amputee Athlete compared to Able Bodied Athlete (Rajťúková et al., 2014)

User Research Goals

The research goals of this project for the unilateral transtibial Hood to Coast athlete is to understand user specific challenges, and the limitations of the current market products for adaptive athletes. In terms of the adaptive training legging, the research questions are intended to narrow the comfort features that are most important for the athletes. It is important to determine what are the key patterning locations for prosthetic compatibility for the amputee athletes. Finally, for the prosthetic blade outsole the research is focused on the improving the biggest athlete challenge in regards to their most important features. Identifying the athlete challenges and the most important area of improvement, is essential to creating innovative solutions.

Research Methods

For the transtibial Hood to Coast adaptive athlete, I will be using several research methodologies to collect data and information to inform the design project. The primary method will be interviews and surveys. The survey questions will be looking for areas of improvements, usability, durability, and comfort. The target user will be the amputee

adaptive athletes on the team as well as disability advocates active on social media such as LinkedIn, Instagram, and Facebook. In addition, the survey will be posted on online communities and forums such as Facebook groups and Reddit.

Furthermore, in person interviews will be conducted to collect user information. It is crucial to get user feedback directly from amputee athlete on the team. They will provide important athlete insight into the current product weaknesses and opportunities for improvement. It is also planned to conduct interviews with industry experts and designers in the field of prosthetic. Furthermore, interviews will be conducted with the local advocacy group such as Adaptive Sport by Northwest which has connections with the adaptive athlete community in Portland.

Finally, it will be beneficial to conduct user information as “being the customer”. While it is essential to design for the transtibial Hood to Coast adaptive athlete, for early prototypes it may be beneficial to “modify” an able-bodied athlete to receive early user feedback. For final prototype iterations and user feedback the only adaptive athletes will be utilized. Collecting user information through surveys, in person interviews, and “being the customer” will provide invaluable athlete insight and determine key areas of improvement and innovation.

To collect and analyze the data I will follow a monthly plan where I will evaluate the information to inform prototype designs and testing.

- September – October: Interview athletes and prosthetist to evaluate problem to be solved and feasibility of solutions.
- October – November: Send out surveys and continue interviews to refine product areas of improvement and criteria of testing.
- November – December: Collect survey data and follow up key expert interviews to make changes as needed.

User Research

An athlete interview will be conducted with the Hood to Coast adaptive athlete who use a prosthetic blade for running. The research seeks to understand the athlete and their unique adaptive athlete experience and challenges. The user research will ask about their training and competition experience with the current market offerings.

Likewise, it would be insightful to learn if the athletes are making modifications to their own products so as improve their product's performance. The interviews will be conducted as an open-ended conversation structured around answering the key research questions. Doing so, will allow for the collection of qualitative information and provide further insight and design direction going forward.

The interview questions will be asked below depending on the athlete and the product that they use.

Prosthetic Leggings

1. What are the most important features that you look for in a running legging?
2. What is the biggest challenge that you encounter with your running apparel?
3. How important is amputee compatibility, fit, stretch zones, and ventilation in a running legging?
4. What is the current legging that you are using, and did you have to make any personal alterations?
5. What factors do you consider to be important when looking for a running legging? (Customize fit, durability, lightweight, breathable materials)
6. Are there additional insights not covered by this survey/interview?

Prosthetic Blade

1. What types of prosthetic blade models do you use for racing?
2. What are the most important features that you look for in a prosthetic blade in particular the outsole?
3. What is the biggest challenge that you encounter with your prosthetic blade outsole?
4. How important is durable traction outsoles, quick interchangeable design, durability, grip, use in multiple surfaces, gravel/sand, pavement etc.?
5. Are there additional insights not covered by this survey/interview?

Survey and Interview Results

The training leggings and prosthetic blade surveys were sent to the Hood to Coast adaptive athlete teams from 2022 and 2021. The athletes were contacted on their social media profiles on Instagram and LinkedIn. The prosthetic blade survey had three responses, Dee Palagi, Taylor Haines, and Erica Korpi. These three athletes agreed to be interviewed and I asked them more questions about their Hood to Coast athlete experience. Finally, Dee Palagi was able to put me in contact with a prosthetist Jeremy Bilow who specializes in prosthetic athletes. I interviewed Jeremy and asked him more

technical questions about the different market prosthetic leg options and the prosthetic design.

Survey Results

Please describe your experience with your current prosthetic in respect to performance, comfort, and ease of use. Are there areas of improvement that you wish you had?

It's wonderful for tracks, even roads and sidewalks. Improvement is running on slanted settings. Especially thinking of slanted uneven roads

Sometimes if I hit a root in the middle of my tread, I lose my balance.

it's been comfortable, I have never tried anything else to compare though

Have you had to make any DIY changes to your prosthetic blade to improve performance, if so what changes?

No

N/a

electrical type to help with the split sole since the show sole breaks

If you had the option to purchase a new prosthetic blade, what brand and model would you purchase? Why would you prefer this new model?

Fillauer Obsidian - split toes design better for uneven roads

Not sure!

I would have to trial different models and or understand how other models would be better

What would you like the broader sports product design industry to know about your athletic needs?

Ideally looking at different sole options that enhance the user's ability for their blade. Light weight, road traction vs trail traction

Unsure

yes

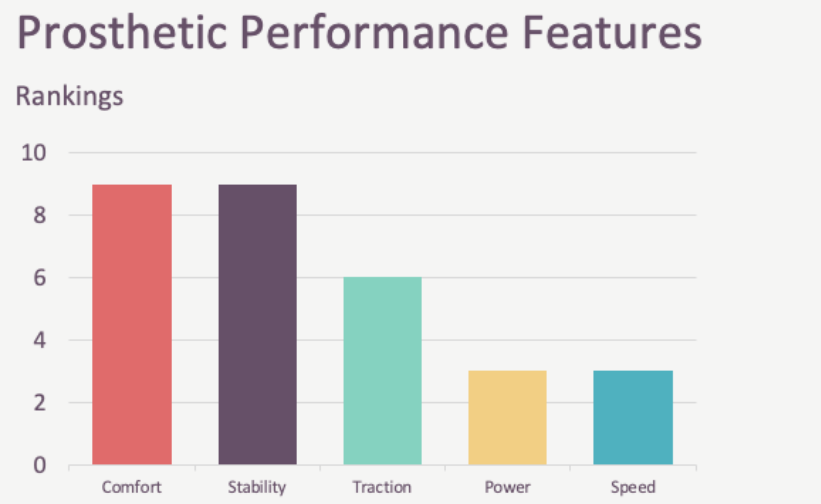
Do you feel the current apparel on the market fit your athletic needs? If not, what would you like to be changed?

I wish for a day when I can find a pair of leggings that I can zip up to swap prosthetics out or remove my leg to clean sweat.

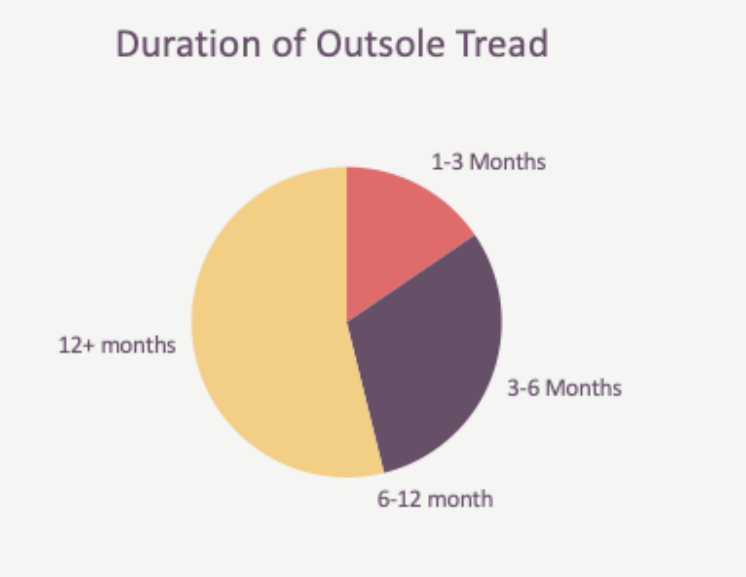
Mostly, I feel like it does! Occasionally I would like the option to zip leggings up for better leg access on my left side.

yes

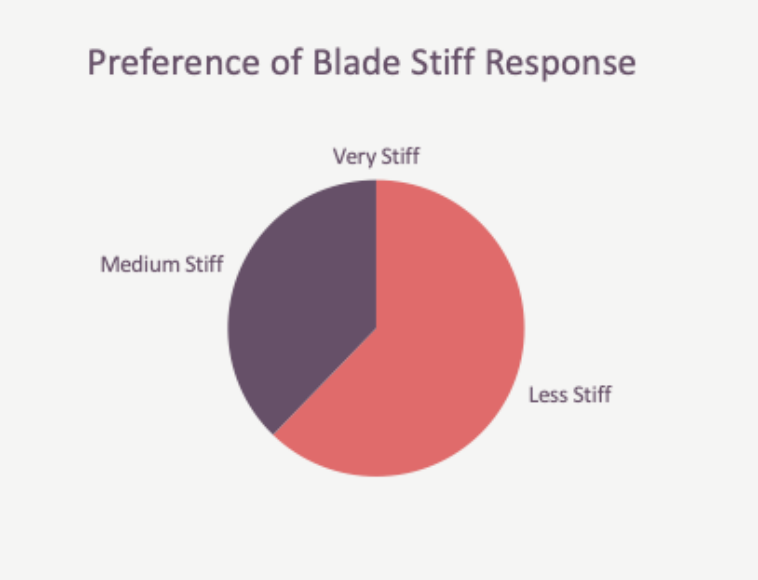
Ranking of Performance Features (10 Most important – 1 Least Important)



Duration of Outsole Tread before Replacement



Preference of Prosthetic Blade Stiffness



Survey Summary

The survey results were insightful in highlighting the key performance features that prosthetic athlete cared about the most. For example, the three most important features were comfort, stability, and traction. The survey revealed that 67% of athletes prefer a less stiff prosthetic blade, or a blade with more energy absorption. Interestingly, two athletes requested a pair of zip leggings that would ease the removal of their leg to

clean sweat. The majority of responses reported that their outsole lasted longer than 12 months. One response said that the Filauer split toe blade is a design that they would purchase next.

Interview Takeaways

Dee Palagi

Dee validated the need for interchangeable tread outsoles for different surfaces. She educated me on the difference between a running prosthetic and walking foot. She commented that her current Filauer prosthetic blade has an outsole that is glued on and is not interchangeable. In addition, she mentioned that the split toe design is not durable, and she had to tape it. She agreed to continue helping me with my project and she put me in contact with Taylor and Jeremy.

Taylor Haines

Taylor mentioned that the uneven terrain such as roots would cause her to lose her stability. She was very interested in an interchangeable tread option that was good for trails and wet pavement when training for the Hood to Coast Race. Taylor agreed to be a prototype tester. She was also interested a legging with a zipper that ran from the knee to the thigh.

Erica Korpi

Erica suggested looking at leggings that not only made the removal of the prosthetic easy but also different bottom options for recovery and rest during the different legs of the Hood to Coast race. Erica had modified sweatpants that she used during the race to sleep in, and a pair of recovery leggings when she was waiting for her turn. She confirmed that split toe prosthetic blade is better for curved and uneven terrain.

Jeremy Bilow

Athletes are most concerned about efficiency and simple installation. If the time to change out the different tread outsoles was long and the process was cumbersome athletes will forgo the different tread options. He also noted that the thickness of the tread outsole will need to correspond to the thickness of each prosthetic blade. There are different blade sizes depending on the weight of the athlete. He suggested looking at using Fidlock hardware or industrial Velcro for an interchangeable outsole. Last Jeremy mentioned that that wide opening of a legging for prosthetic should have some snaps to keep it secure during the prosthetic leg removal and cleaning process.

Performance Testing Plan

Design Project Statement

Considering the physical and gear challenges for the So Every BODY Can Move unilateral transtibial athlete, how can we make a prosthetic compatible training leggings, and create a versatile blade outsole to enhance athlete performance in the Hood to Coast Relay race?

Step One: Competitor Products

The competitor products for the training legging, and prosthetic blade outsole that I will use as benchmark for my prototype testing are listed below.

Training Leggings

Brand	Style	Size	Link	Cost
Nike	Go Women's Firm Support	M	https://www.nike.com/t/go-womens-firm-support-high-waisted-7-8-leggings-with-pockets-tGXxmG	$110.00
Curves N Boots	Amputee Leggings	M	https://www.curvesncombatboots.com/products/amputee-right-leg-below-the-knee-black-leggings-with-pockets	$60.00

Prosthetic Blade Outsole

Brand	Style	Size	Link	Cost
Nike x Ossur	Flex Run	NA	https://www.ebay.com/itm/325433997980?chn=ps&mkevt=1&mkcid=28&srsltid=AfmBOoqhnUQME1ti38E1Z8vt1eySIN12wtr8-ExjvBgI2m5QMnNnaZJ3i4Y	$448.47

Step Two: Performance Metrics

The competitor products for the training leggings, and prosthetic blade outsole will be tested by several performance metrics listed below.

Training Leggings

Don Doff from Walking Leg to Running Leg: Time trial of how long it takes for athlete to transition from walking leg to running leg while wearing the competitor leggings.

Don Doff from Running to Walking Leg: Time trial of how long it takes for athlete to transition from running leg to walking leg while wearing the competitor leggings.

Prosthetic Blade Outsole

Surface Traction: Assess the outsole's ability to provide sufficient traction on various surfaces, including sand, and loose gravel.

Don Doff Outsole Removal and Installation: Time trial of how long it takes for removal and installation of the outsole.

Step Three: Testing Procedures

The competitor products for the training leggings, and prosthetic blade outsole will be tested by the testing procedures listed below. All test participants will be asked to sign a release form before conducting the training leggings and prosthetic outsole testing.

Training Leggings

Don Doff from Walking Leg to Running Leg

Step 1: Athlete is wearing the competitor legging while wearing their walking leg.

Step 2: Record time for user to remove the walking leg and fully install their running leg.

Step 3: Repeat test five times for competitor leggings and prototype leggings.

Don Doff from Running Leg to Walking Leg

Step 1: Athlete is wearing the competitor legging while wearing their running leg.

Step 2: Record time for user to remove the running leg and fully install their walking leg.

Step 3: Repeat test five times for competitor leggings and prototype leggings.

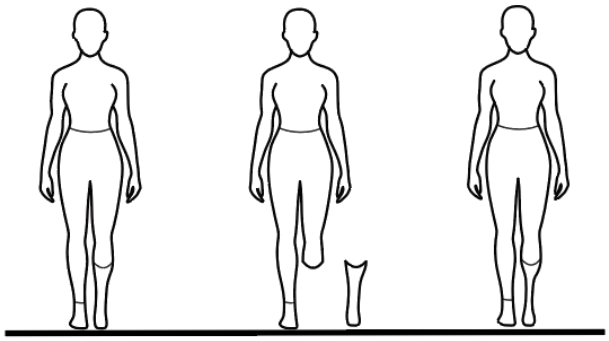


Figure 18: Training Legging Don Doff

Prosthetic Blade Outsole

Traction Test

Step 1: Set up testing rig of force gauge connected to outsole.

Step 2: Weigh down the outsole to 450 grams.

Step 3: Pull weighted outsole using the force gauge and the power drill.

Step 4: Record value of peak force needed to pull outsole.

Step 5: Repeat pull test 5 more times.

Step 6: Repeat steps 2-5 testing for competitor and prototype product.

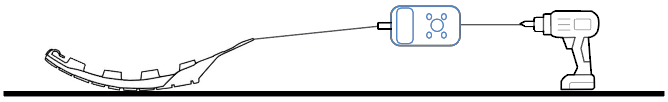


Figure 19: Traction Testing

Don Doff Outsole Installation

Step 1: Set up the prosthetic blade without the competitor outsole.

Step 2: Record time for user to install the competitor outsole as quickly as possible.

Step 3: Repeat test five times for competitor outsole and outsole prototype.

Don Doff Outsole Removal

Step 1: Set up the prosthetic blade with the competitor outsole.

Step 2: Record time for user to remove the competitor outsole as quickly as possible.

Step 3: Repeat test five times for competitor outsole and outsole prototype.

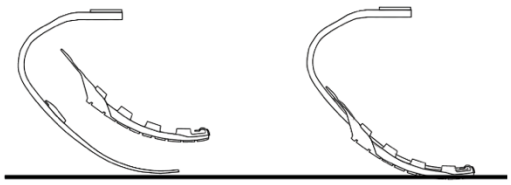


Figure 20: Outsole Don and Doff

Step Four: Data Analysis

Analyze all data by comparing metric results of prototype and competitor product. Repeat the testing procedure for multiple times to ensure reliability of data collected.

Training leggings will result in times for donning on and off, comfort ratings, and timing to complete a transition from their walking leg to their running leg. These results of multiple trials will be averaged to ensure data reliability. The results of this testing will help inform design decisions as benchmarks for my training legging prototypes. The

goal will be to design training leggings that results in a faster time to don on and off than the leading competitor product.

Prosthetic blade outsole testing will result in time trials and force applied for traction. The force in pounds results will be averaged. The tread sole with a higher force in pound average will determine which tread sole has better traction. Finally, after These test results will evaluate if my prototype designs are better than the market competitor product in terms of shock traction, and don doff times.

Step Five: Prototype Process

After initial research and benchmark testing is completed, an iterative prototype process was followed to test design concepts and validate each iteration. It began with a 3D scan of the athlete and their running blade. Different lugs and traction patterns were 3D printed and tested using a force gauge and drill on various surfaces. The outsole attachment technology was finalized after testing various configurations and hardware, ultimately selecting the magnet Fidlock HOOK 20. Measurements from the 3D body scan were used to pattern pieces in CLO3D software (Figure 21). Various attachment methods for the legging sleeve, such as Velcro and snaps, were tested, with magnet snap tape and Bemis silicon grip hems chosen for their ease of removal and attachment.

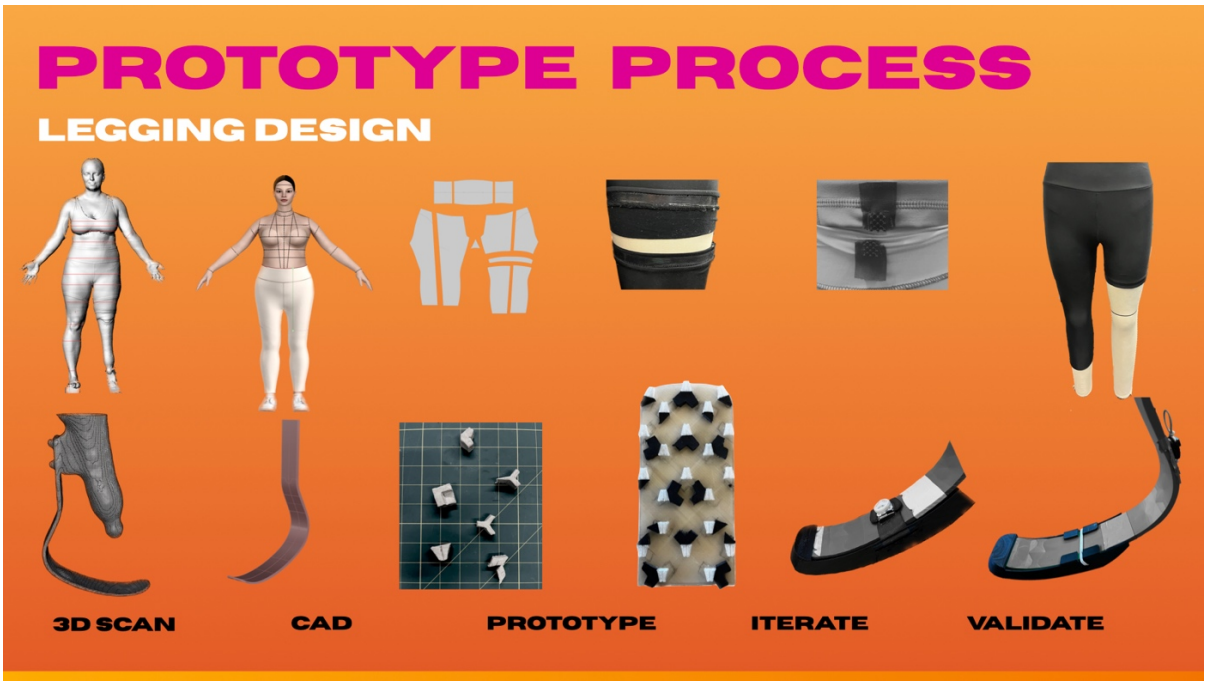


Figure 21: Prototype Process

Step Six: Data Results

The adaptive training legging and outsole prototypes excelled against the competitor market products in terms of don doff times and traction. For the adaptive leggings the prototype used magnets and Bemis anti-slip silicon to create a leg sleeve that don and doffs with the walking leg. The result of the competitor leggings transition from the walking leg to running leg was an average of 17 seconds. The result of the competitor legging transition from running leg to walking was an average 13.8 seconds. In comparison the new prototype design took less time with only an average of 7.4 seconds to go from walking leg to running leg, and only 8.2 seconds to change from the running leg to the walking leg. The percentage change was 56% faster don doff prosthetic walking leg to running leg and 40% faster don doff running leg to walking leg (Figure 22).

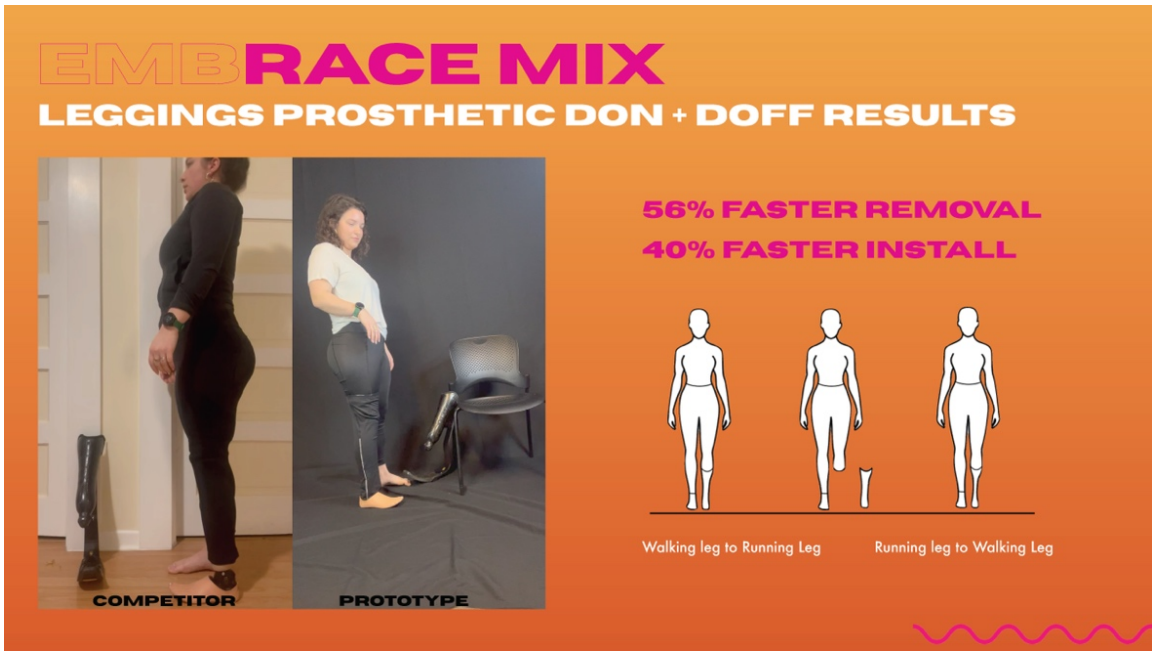


Figure 22: Legging Prosthetic Don and Doff Results

The results of the competitor outsole were an average of 10.23 seconds removal and 19.28 seconds for installation. The prototype outsole was an average of 2.2 seconds removal and 6.4 seconds for installation. The percentage change were 80% faster removal and 68% faster installation (Figure 23).

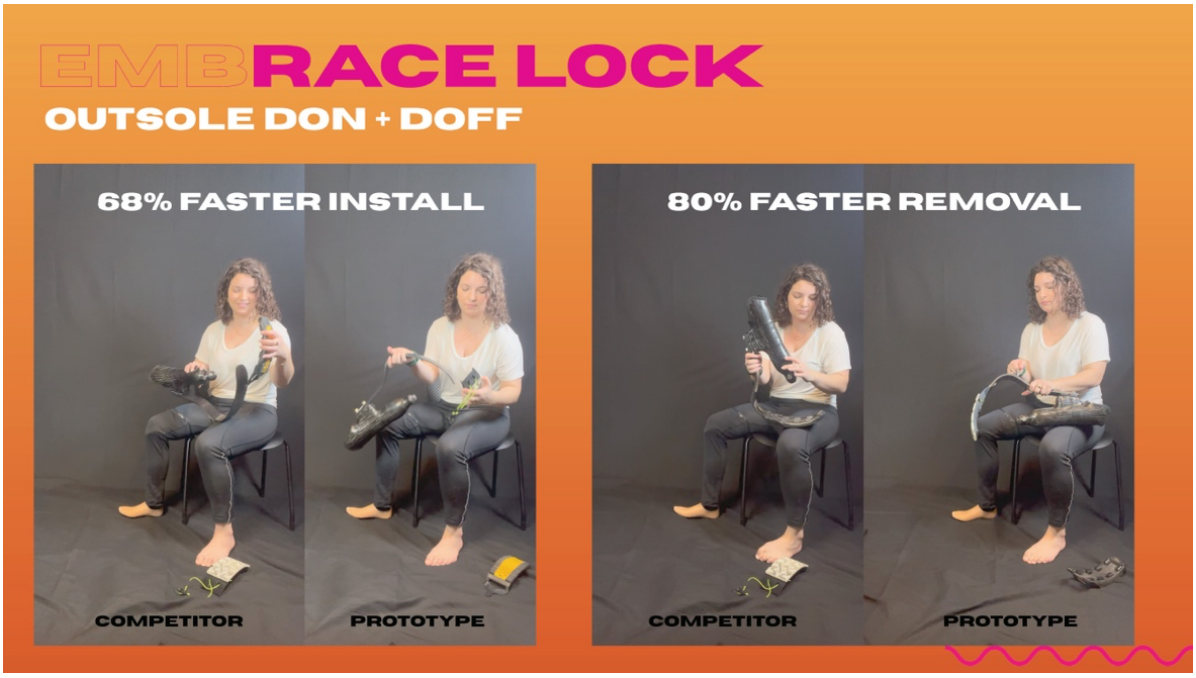


Figure 23: Outsole Don and Doff Results

The results of the competitor outsole traction on the different surfaces were 4.8N for sand and 4.3N for loose gravel. The new outsole designs improved traction by 12.5% or 5.4N on sand, and 28% or 5.52 for the loose gravel (Figure 24). The new outsole gravel traction was updated to a stepped chevron lug and the new sand outsole was updated to a rotating trident lug.

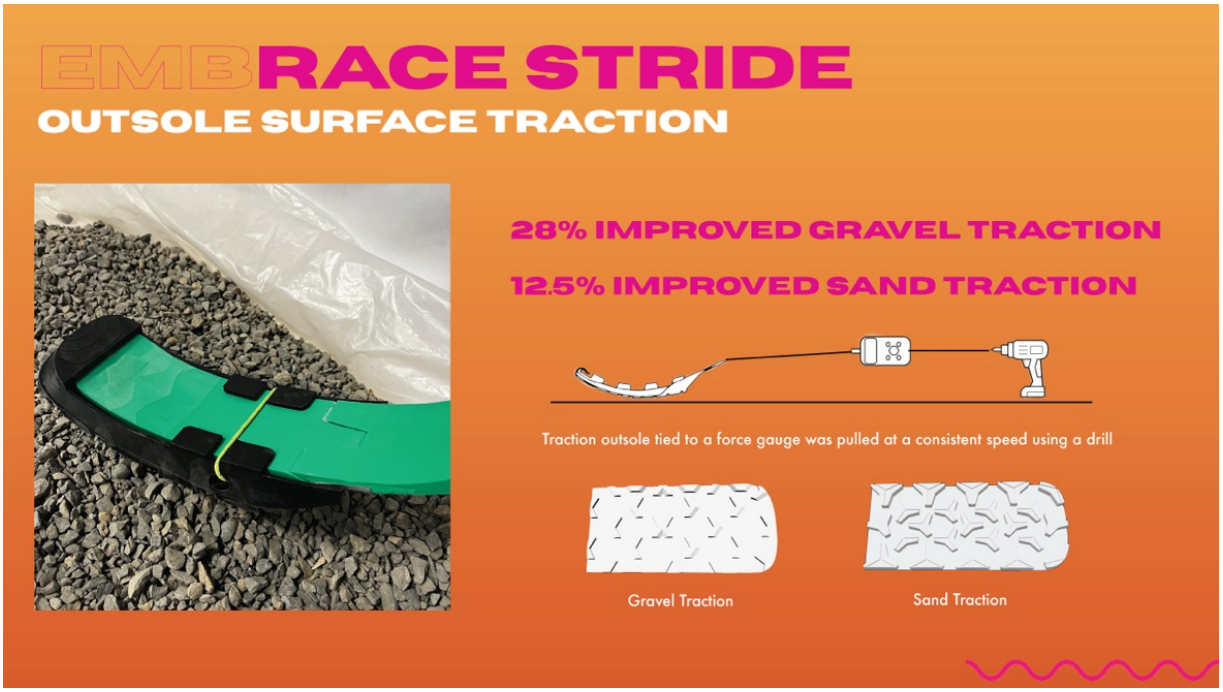


Figure 24: Outsole Don and Doff Results

Strengths Finder

According to Clifton's "Strengths Finder" test (2023), my top five strengths are developer, relator, achiever, discipline, and analytical. In this project, my focus as a developer is on recognizing and celebrating the strengths of adaptive athletes. The thesis aims to acknowledge their progress and potential in sports. As a relator, I value building close relationships and understanding individuals deeply. In this project, I will leverage this strength to build trust with athletes and gather valuable feedback. My achiever strength drives me to overcome setbacks and stay motivated. I will use this stamina to tackle challenging project tasks and endure multiple rounds of product

testing. Discipline is another key strength I will rely on to organize my project and achieve my goals. I understand the importance of staying focused and managing my time effectively. Lastly, my analytical strength will help me break down complex problems into manageable steps and develop a plan for execution. This analytical approach will be crucial in solving intricate problems and refining my designs to create innovations for adaptive athletes.

Project to Career Correlation

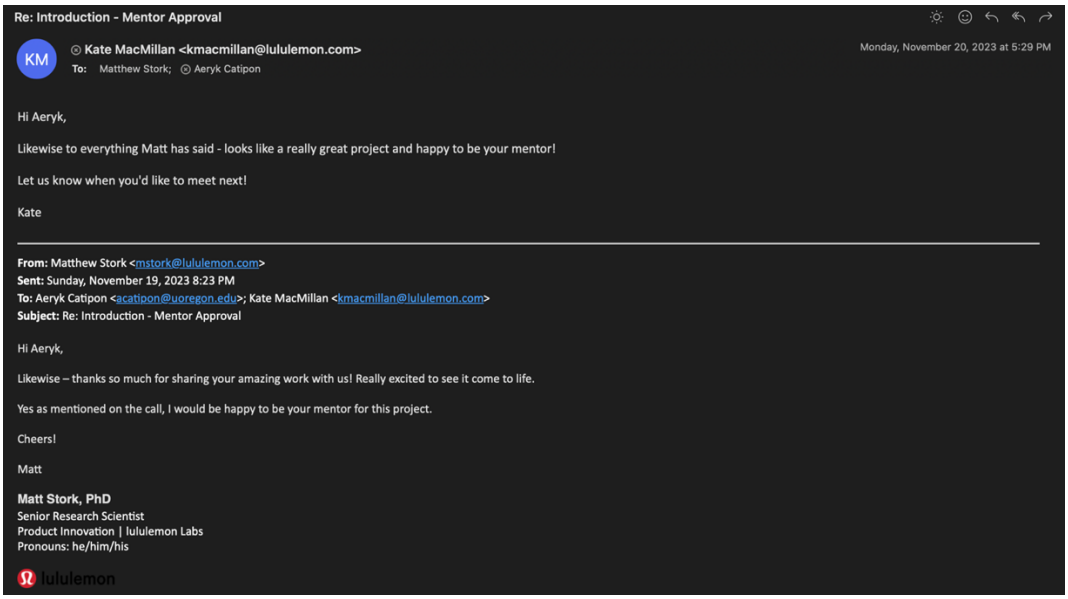
My thesis project supports my career in the sport design industry in three ways. Firstly, it aligns with my interest in trail and long-distance running, such as the Hood to Coast Race, a team long-distance running relay. In five years, I aim to work for a values-driven company in the running industry, specializing in apparel and equipment innovation. This project's focus on running makes it appealing to running-focused companies seeking innovative designs. Secondly, it aligns with my design philosophy of user-centered designs. Designing for adaptive athletes requires essential feedback from athletes, which I believe will enhance my future career development. Understanding athlete needs is crucial for creating innovative designs that improve performance. Lastly, this thesis project will help me build my knowledge and design skillset in apparel, and soft goods. It will improve my apparel patterning skills and require integrating soft goods and material understanding to develop a versatile blade outsole. Developing these skillsets will make me a more versatile and capable designer in the industry.

Mentor Commitment

The mentors that have agreed to support me with my thesis project are Matt Stuart Senior Research Scientist of Product Innovation and Lululemon Labs, Kate MacMilan Design Research Manager at Lululemon, and John Blasioli a designer at Terrazign in Portland.

I will utilize Matt and Kate by meeting with them once a month for 30 minutes to one-hour meetings to discuss progress on my product testing, prototype development, and athlete insights. I hope to use them to develop contacts in the running industry and sport research. Matt has an expertise working with athletes with disabilities prior to

Lululemon, and both Matt and Kate are very knowledgeable of working on athlete centered designs having worked on projects with Olympic Team Canada.



Re: Introduction - Mentor Approval

KM **Kate MacMillan <kmacmillan@lululemon.com>**
To: Matthew Stork; Aeryk Catipon
Monday, November 20, 2023 at 5:29 PM

Hi Aeryk,

Likewise to everything Matt has said - looks like a really great project and happy to be your mentor!

Let us know when you'd like to meet next!

Kate

From: Matthew Stork <mstork@lululemon.com>
Sent: Sunday, November 19, 2023 8:23 PM
To: Aeryk Catipon <acatipon@uoregon.edu>; Kate MacMillan <kmacmillan@lululemon.com>
Subject: Re: Introduction - Mentor Approval

Hi Aeryk,

Likewise – thanks so much for sharing your amazing work with us! Really excited to see it come to life.

Yes as mentioned on the call, I would be happy to be your mentor for this project.

Cheers!

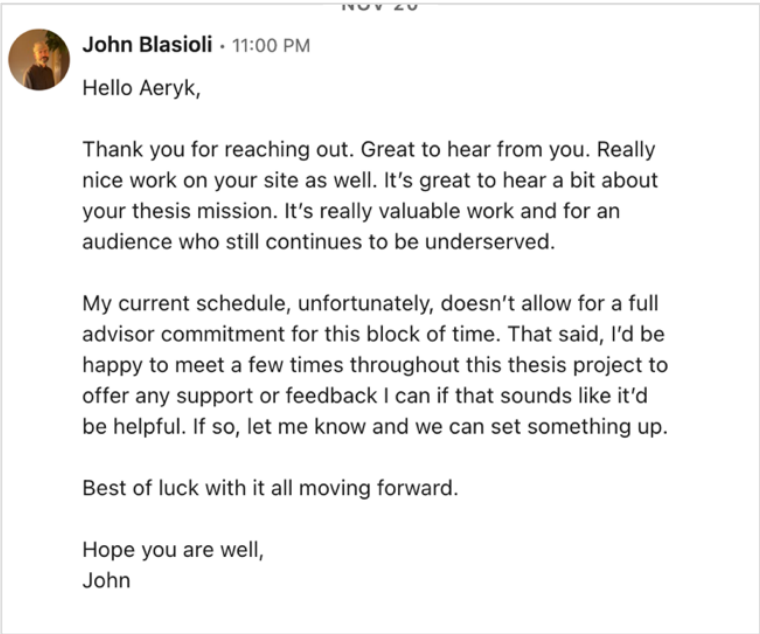
Matt

Matt Stork, PhD
Senior Research Scientist
Product Innovation | lululemon Labs
Pronouns: he/him/his

lululemon

Figure 24: Mentor Email Commitment

I reached out to John Blasioli on Carly's recommendation for his expertise with patterning and sewing. John has prior experience working for Nike innovation before starting his own apparel brand and working as a designer for Terrazign. While John is unable to fully mentor, he did agree to meet up several times to provide feedback. I believe he would be a great resource when it comes to patterning the adaptive athlete apparel and providing material feedback on my prototype designs.



John Blasioli · 11:00 PM

Hello Aeryk,

Thank you for reaching out. Great to hear from you. Really nice work on your site as well. It's great to hear a bit about your thesis mission. It's really valuable work and for an audience who still continues to be underserved.

My current schedule, unfortunately, doesn't allow for a full advisor commitment for this block of time. That said, I'd be happy to meet a few times throughout this thesis project to offer any support or feedback I can if that sounds like it'd be helpful. If so, let me know and we can set something up.

Best of luck with it all moving forward.

Hope you are well,
John

Figure 25: Advisor Feedback

Travel Plan Proposal

A proposed Travel Plan will supplement the research to better understand the athlete experience, take final photography, and product validation to be worn by the athlete. The travel location and date were determined because the athlete will be in Washington D.C. for a law firm fellowship during the time of May 16th to July 25th.

Travel Plan Logistics

When: May 24 to May 27

Where: Washington D.C.

Who: Taylor Haines

Itinerary

May 24th

Uber to PDX

Departure to Washington D.C.

Housing in Washington D.C.

May 25th

Meet with athlete at Rock Creek Park Washington D.C.

Product testing and athlete validation

Product photography and videography in wooded outdoor situ

Housing in Washington D.C.

May 26th

Product photography and videography in Georgetown waterfront park

Housing in Washington D.C.

May 27th

Return to Portland

Uber home

Travel Cost Estimates

Travel Expense	**Cost**
Flight	$1000
Car Rental + Gas	$160
Lodging	$0
Food per diem	$548
TOTAL	**$1,708**

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