

FEMALE-CENTRIC SOCCER GEAR INFORMED BY  
BIOMECHANICS AND DESIGN INSIGHTS

by

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A THESIS

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Soccer is a demanding sport that requires players to perform quick multiplanar movements on variable natural and artificial turf surfaces. Despite over a century of women's participation in soccer, soccer footwear and other sports gear is primarily informed by research on male athletes by default. In fact, only 6% of literature in sports and exercise science is focused specifically on females (Cowley et al., 2021). This thesis project includes a literature review on soccer biomechanics studies, an analysis of plantar pressure data from a 20-athlete soccer-specific running and cutting task study conducted at the Bowerman Sports Science Center, and an exploration of qualitative insights from athlete-centered ethnographic design research. This project exists at the intersection of quantitative biomechanics data and qualitative design insights tailored to female athlete needs. The first section asks, how have previous biomechanics studies evaluated soccer footwear performance? The second section asks, how does plantar pressure distribution, measured by force-time integral, differ between males and females for cutting and sprinting tasks? Lastly, the final section culminates in an insights-driven research and design process that addresses the question, how might we empower female soccer athlete performance by building trust in supportive gear? One possible solution proposed at the end of this thesis is an insole design concept that is compatible with the female athlete's existing gear and might help mitigate the risk of overpronation that accompanies knee and ankle

instability. By combining scientific data with design insights and lived experiences, this thesis aims to contribute to the sports product design literature by amplifying the voices of female athletes.

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I am grateful for my family of Cambodian immigrants who fled from the Khmer Rouge regime in the 1970s and 80s and overcame adversity to build a steady foundation for Cambodian Americans to thrive in the United States. I am immensely grateful for my mom, Sokheta Yi-Saing, for teaching me unconditional love and compassion. I appreciate my friends—notably,

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I am on a journey to break cycles of systemic oppression by using my research and design skills for social justice. My thesis aims to address the gap in female soccer research and design. I dedicate this thesis to those who embody female solidarity and power: my mom; Ma Ohm and other aunts; Ma Yeays (grandmothers); and my sisters Emilia “Mia”, Willow, and Mya. Thank you (ស្រីមេអ្នកគុណ).

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## Introduction

My design practice is centered around research and the concept of design justice, “an approach to design that is led by marginalized communities and that aims explicitly to challenge, rather than reproduce, structural inequalities” (Costanza-Chock, 2020). The central objective of this thesis is to advocate for female soccer athlete needs using biomechanics and design research insights.

Soccer demands dynamic multiplanar movements like angled cuts, jumping for a header, slide tackling, balancing to kick, turning, and intermittent running. Although women have been participating in soccer for over a century, the male body is the default in athlete research and consequent soccer gear design. In fact, only 6% of existing sport and exercise science literature focuses specifically on female athletes (Cowley et al., 2021). Females and males experience differences in anatomical alignment, ligament laxity, neuromuscular control techniques, and landing mechanics. Coaching and practice interventions can improve disparities in biomechanics.

Unfortunately, the lack of female athlete data-informed gear design, combined with increased player load, demanding schedules, variable playing surfaces, and disparities between men’s and women’s sports investment can hinder female athlete performance and exacerbate injury rates. For example, female soccer players are 2-3 times more likely to tear their anterior cruciate ligaments (ACLs) than male soccer players (Montalvo et al., 2019; Waldén et al., 2011). Approximately 70% of ACL injuries are noncontact and often occurs during the deceleration phase of a change in direction combined with an internal knee rotation (Mandelbaum et al., 2005). Outsole design can greatly influence an athlete’s biomechanics on the playing surface, so it is important to understand sex-based biomechanical differences (Kulesa et al., 2017). It is

possible that the length of studs selected for default male bodies and integrated into commercial cleat designs provides too much rotational resistance for female bodies, which risks foot fixation in the turf and potentially harmful knee and ankle stress when trying to change direction (Thomson et al., 2022).

Interdisciplinary collaboration between coaches, athletes, scientists, engineers, researchers, and designers could help achieve the optimum combination of performance and injury prevention criteria for soccer gear so that female athletes feel more empowered to play throughout their careers. This undergraduate thesis project for the Robert D. Clark Honors College and Department of Product Design encapsulates a literature review of soccer biomechanics research, an analysis of plantar pressure data from a recent 20-athlete<sup>1</sup> study at the Bowerman Sports Science Center, and applications of ethnographic product design insights to an insole. The purpose of this project is to contribute to the female sports product design research with quantitative and qualitative insights, and to amplify the stories of female athletes who are sometimes disproportionately affected by injustices in sport.

<sup>1</sup> The term “athlete” rather than “subject” helps humanize the biomechanics research process that can otherwise be daunting.

## Section I: Sports Science Literature Review

### Guiding Question

How have previous biomechanics studies evaluated soccer footwear performance?

### Soccer Performance Footwear Parameters

In soccer, performance is a broad term that can be measured in many ways. In standard matches, athletes wear a uniform consisting of a top, shorts, shin guards, socks, and football boots. Soccer footwear permits quick movements with enough traction and stability on various types of turf surfaces (including firm ground, soft ground, artificial turf, indoor, and street surfaces). Compared to running footwear, an athlete's performance in soccer footwear cannot simply be measured by speed or distances covered. Instead, three complex factors must be considered: shoe-surface interaction, shoe-ball interaction, and shoe-foot interaction. Figure 1 shows that the basic components of a soccer cleat are the upper, heel counter, insole, and outsole where studs are connected to (Blanchard et al., 2018).

#### *Shoe-Surface Interaction*

Existing literature suggests that outsole and stud design primarily affect shoe-surface interaction, aside from the shoe wearer's movements. In general, cleated footwear may have bladed studs, elliptical or conical studs, or a hybrid of both on the outsole. Bladed studs have an overall geometric polygonal shape, while elliptical studs are rounded. Hybrid outsole patterns combine the benefits of each type of stud. A systematic study by Silva et al. (2017) noted that bladed studs may improve performance during cuts in natural and synthetic grass when compared to elliptical studs. The tradeoff is that bladed studs are associated with higher risk of

lower extremity injury due to higher pressure on the side of the foot when compared to elliptical studs (Silva et al., 2017). Most high-performance cleats for speed lean towards bladed studs on the outsole as they provide higher traction for quick movements.

Select studies use mechanical setups to test soccer cleat performance at simulated points in a movement. For example, the Clarke and Carré (2010) study developed a translational traction apparatus that applied increasing amounts of horizontal force to a vertically loaded stud plate penetrating a natural turf surface and a 3G artificial surface; the setup was meant to simulate a player pushing off into a sprint, which is a moment in time where Kirk et al. (2007) argues that a player is at risk of losing performance. Rather than looking at human performance parameters, the mechanical study used vertical displacement quantities to measure stud penetration, plate penetration, traction force, and effective cross-sectional area of the studs (Clarke & Carré, 2010). Although mechanical test methods allow for high repeated measures, lack of human subjects testing in these studies on performance should be questioned as they do not reflect natural movements. In contrast to the mechanical studies, one study collected high-speed footage during two youth training seasons on natural grass and artificial turf to best represent natural movements during play (Kirk et al., 2007). This ethnographic observational study is beneficial because it includes unpredictable environments and natural movements that humans use to adapt. Meanwhile, laboratory studies provide the benefits of standardized surfaces, tests, and tools that minimize covariates while still including human movements.

### *Shoe-Ball Interaction*

Furthermore, the material design and structure of the shoe upper impacts shoe-ball interaction. Cleats constructed with asymmetric lacing, such as the Nike Phantom Luna 2, intend

to aid in maximizing space in the medial touch zone of the boot where the ball is contacted most frequently for passing. Some existing uppers feature microfiber, suede, or rubber textured touch zones to aid in ball control. The Nike Phantom Luna 2 and Phantom GX 2 Elite employs Nike GripKnit, TPU-coated yarn that enhances grip on the ball without adding a layer of coating on the medial side of the upper. The adidas Predator Edge.2 firm ground (FG) cleat also features rubber ridges to aid in ball control. Similarly, the Puma Future 8 Pro Light Up integrates raised mesh lines and GripControl Technology.

### *Shoe-Foot Interaction*

Shoe-foot interaction is impacted by the player's foot morphology, moisture management, sock choice, and insole choice. It is evaluated with subjective comfort and fit perception, plantar pressure distribution, cushioning, and bending and torsional stiffness (Kulesa et al., 2017). Adaptations to the fit, functions, and performance benefits of a football boot are limited by its small size and lack of a midsole.

In other types of performance footwear, the midsole typically provides cushioning, stabilizing, motion control, and energy return properties. For example, the Brooks Adrenaline GTS 24 features a nitrogen-infused foam midsole, a 39 mm heel, and plastic GuideRails on the medial and lateral sides of the foot for torsional stability. Instead of a midsole, soccer cleats have a thin insole and an outsole with studs for a more direct connection to the ground.

There is an opportunity for the insole to compensate for the lack of midsole in a soccer boot. For example, the Puma Future 8 Pro Lightup includes a lightweight removeable sock liner with NanoGrip technology. Yet some companies do not capitalize on the potential benefits of a custom insole. Namely, the Nike Mercurial, Phantom GX, Hypervenom house a simple single-

material 4 mm foam factory insert with foam covered by a thin polyester fabric that degrades easily over time. Football boots are known to run narrow in sizing and lack arch support. A small number of players opt to remove the factory inserts from their cleats and replace them with over the counter or custom insoles for improved comfort and arch support. It can be especially hard for female athletes to find insoles that are specially designed for their foot and shoe.

Players have diverse foot morphologies that might not be accommodated by the standard football boot that is narrow and stiff. Sex-based differences in foot morphology are summarized in Figure 1, where the male foot is generally shaped like a rectangle and the female foot is like a triangle that narrows in the heel and widens in the front. In general, the female foot has a more discreet big toe, shorter and narrower ball to heel length relative to body height, shorter outer length, more medial curvature, narrower instep circumference, a higher arch, and a narrower heel. At the fundamental level, a female-centric shoe would begin with a women shaped last and data from biomechanical studies to account for these anatomical differences.

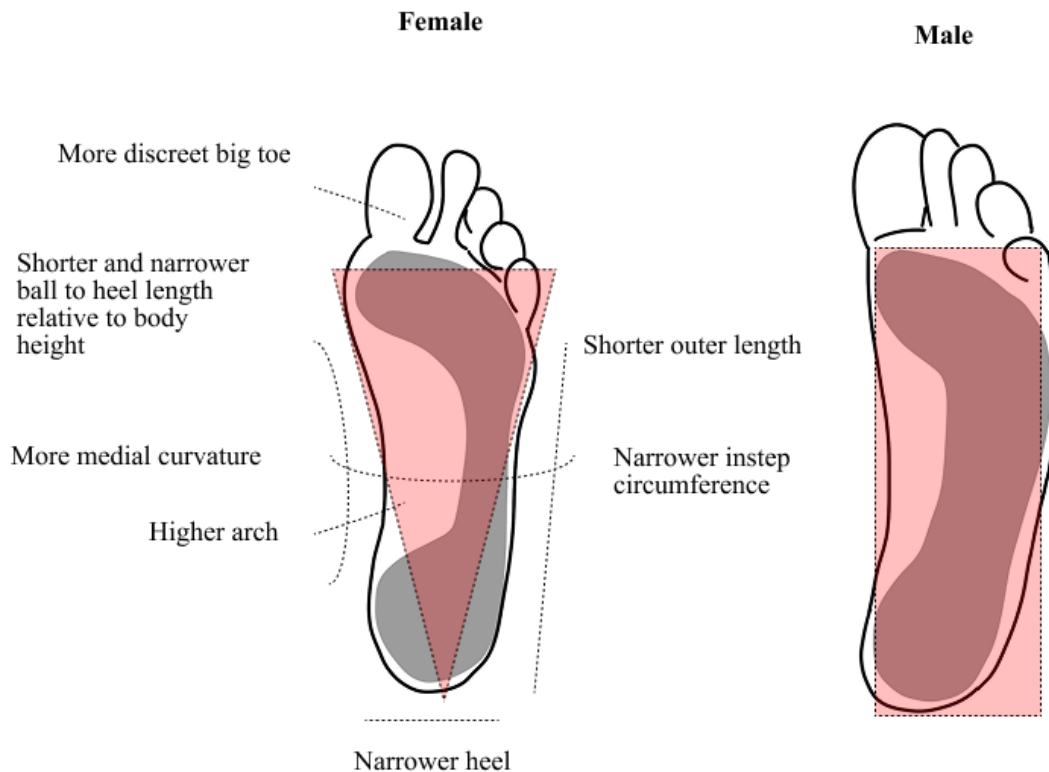


Figure 1: General differences between female and male foot morphologies

In general, the female foot is shaped like a triangle that narrows in the heel and widens in the forefoot. The female foot tends to have a more discreet big toes, shorter and narrower ball to heel length relative to height, greater medial curvature, a higher arch, narrower instep circumference, and a shorter outer length than the male foot. Meanwhile, the typical male foot is shaped more like a rectangle.

Fortunately, some companies are beginning to invest in research and development for women's specific cleats. IDA Sports is a small company that began in 2018, founded upon several female-specific cleat models employing Women's Fit. IDA's Women's Fit includes a deep fitted heel cup and wider toe box to allow for relatively greater toe splay than cleats for male feet. Larger sports companies feature football boots accommodating female foot morphologies as well. However, Nike, Puma, and adidas sometimes advertise the women's

model of a cleat in a unisex model as well, which brings the question of whether the cleats are even optimized for women.

Over the past decade or more, an increasing amount of pre-professional and professional athletes have adopted grip socks to improve the fit within the shoe. Build-up of moisture from bodily sweat or environmental conditions can lead to sliding within the shoe, blisters, or general pain and discomfort. Grip socks designed with zones of knit cushioning, ventilation, compression can aid in comfort, but it has tradeoffs for performance. While the use of grip socks might be rising among athletes, it is unclear if they provide a performance benefit, somatosensory feedback, or have a placebo effect (Buck & Shultz, 2024). Buck & Shultz (2024) conducted a study with 4 male athletes and 7 female athletes in normal soccer socks and TRUsox® 3.0 Mid-Calf Crew Length Grip Socks. They found that found inconsistent significant differences in plantar kinetics, including that compared to normal soccer socks, grip socks improved performance during dribbling, dominant limb juggling, and ball striking at three distances, but decreased 180-degree change-of-direction performance. Hindfoot impulse was smaller during the 45- and 90-degree change-of-direction drills in grip socks (Buck & Shultz, 2024).

### **Limited Female-Specific Soccer Footwear on the Market**

In *Invisible Women: Exposing Data Bias in a World Designed for Men*, British feminist author Caroline Criado Perez (2019) outlines examples of how data biases due to the patriarchy and exclusion of females from research cause inequities that permeate the workplace, city planning, healthcare, and design. Many products are designed for the archetypical white male by default (Caroline Criado Perez, 2019). While there have been promising efforts to raise

awareness for women's sports through increased media coverage; name, image, and likeness (NIL) deals for National Collegiate Athletic Association (NCAA) athletes; and policies for equal pay, one can argue that there is not enough attention being directed towards female-specific sportswear. Female athletes shopping at their local sportswear store typically encounter products that are marketed for females and designed with the “shrink it and pink it” mindset, which is analyzed in Harvard University's Advanced Leadership Initiative Social Impact Review (Korellis Reuther, 2022).

When applied to soccer footwear, the “shrink it and pink it” product strategy would result in a narrower version of a male-centric cleat—to accommodate for generally smaller female foot sizes—and a pink or other feminine color finish. Consequently, female players with medium to wide feet may have to opt for one size up or a men's boot to fit. Although soccer is a popular sport for both males and females, existing soccer cleats on the market are biased toward male biomechanical data. One previous study that evaluated plantar pressure distribution patterns during soccer-specific tasks only used male subjects (Eils et al., 2004). Another study that investigated performance maintenance and perceived foot comfort pre- and post-match only recruited male university soccer players to test “sprint boots,” specialized soccer cleats marketed for enhancing speed performance (Kryger et al., 2021). Similarly, the study on subjective perception and objective evaluation of ball handling performance only had male subjects (Sterzing et al., 2011). In retrospect, many of the articles referenced in this literature review only included male subjects, which further supports that the male is the default body and intended user to benefit from research findings when they are applied to product designs.

In recent years, sportswear companies have released products or statements of intention to release products designed for the female soccer player. These companies seem to focus on fit, which makes sense because a questionnaire given to 304 females and 204 males by Althoff and Hennig (2014) found that only 50% of females and about 60% of males were satisfied with their shoe fit. In the questionnaire, comfort and stability were the top two preferred shoe characteristics for both sexes, though they were significantly more important for females. Females also judged injury protection as more important than males, which might suggest that females are more wary of how improper cleats can be dangerous and risk injury (Althoff & Hennig, 2014).

IDA Sports is a relatively new and small company that was established in 2018. IDA Sports identified itself as having launched the first cleat specifically designed for women in 2020 (IDA Sports, 2024). The IDA Sports website claims that IDA cleats are “backed by science” and that IDA “consulted researchers and podiatrists and changed the stud configuration to support a woman’s body better.” A detailed research methodology behind IDA cleats, including the Classica and Rise models, is inaccessible; however, based on the website descriptions intended for consumers, IDA seems to emphasize proper boot fit for female comfort, improved performance with stability of the foot inside the shoe, reduced preventable pain and blisters, and reduced ankle and knee injury risk. IDA claims to have tested prototypes on both amateurs and professionals. The intention behind IDA Sports’ female soccer cleats is promising, but they have yet to be adopted widely in women’s sports leagues. Recently in March 2025, IDA partnered with Women’s Elite Rugby (WER) and World Rugby Shop (WR) to be the official footwear partner of WER. Shortly after in April 2025, IDA announced its official footwear partnership

with the USL Super League, the highest women's professional soccer league, adjacent to the National Women's Soccer League (NWSL). USL Super League players will receive a complimentary pair of IDA's Rise cleats and hopefully increase the awareness and adoption of female-specific footwear.

Larger companies, including Nike, adidas, and Puma, have also chimed in on their intent to design a soccer cleat for females, though research is still ongoing. In 2020, Puma released the Ultra 1.3 speed performance boot in a unisex fit and for the first time, a regular to narrow women-specific fit with a lower instep, lower midfoot volume, and outsole customized with conical studs based on "research, data, and player feedback" (Haidarovic, 2020). PUMA advertises Ultra 5 Ultimate Brilliance Women's Fit designed with female-specific measurements of volume and instep height, but it uses PUMA's FastTrax Stud design based on academic research and traction studies that aren't specified to have female subjects. In 2023, Nike released the Phantom Luna with larger Nike Gripknit ball touch zones to accommodate relatively smaller female feet, a snug fit around the ankle that female athlete research participants asked for, and a circular Nike Cyclone 360 stud pattern in the forefoot and heel to improve rotational traction (Nike, 2023). Nike's press release for the Phantom Luna sensationalizes the boot as the "most innovative and researched women's-led boot in company history." The Phantom is often misperceived as a female-centric cleat even though it is sold to both male and female players. For science and education, it would be ideal if the research methods and results behind each of the company's cleats designed fully or in part for females were made public, but it is understandable that this type of knowledge sharing would hinder capitalistic efforts.

### *Previous Soccer-Specific Studies*

Previous human-subject laboratory studies have evaluated soccer cleat performance based on the speed of dynamic sport-specific tasks, such as running on a slalom (cutting) functional traction course versus an acceleration course (De Clercq et al., 2014; Sterzing et al., 2009); subjective perception of foot and ankle stability, shoe-surface grip, shoe comfort, rotational load, and general appreciation of the shoe on dry and wet artificial turf conditions (De Clercq et al., 2014); kicking accuracy and pressure between the shoe and ball (Hennig et al., 2009; Sterzing et al., 2011); and forefoot loading during cross cut and side cut tasks on FieldTurf (Queen et al., 2008).

In terms of shoe-foot interaction and shoe-surface interaction, plantar pressure distribution data has been used to explain performance differences between footwear designs (Hennig, 2014). Load distribution across the foot can be modified by the design of uppers, insole material and shape, and outsole stud length and configuration. For example, the special heel cup shape on the Nike Mercurial Superfly II contributed to the cleat's 40 and 60% lower heel peak pressure values during running compared to the adidas F50 adizero TRX, Pelé Trinity 3E, and Puma V1.11 (Hennig, 2014). Hennig (2014) suggests that anatomically shaped soles might help lower the load in certain areas of the foot that often bear the most pressure, such as the forefoot. Pressure distribution patterns also depend on the type of movement and speed, which is why previous studies examined shoe-foot interactions during different sport-specific tasks like cutting and accelerating.

The pedar® system can provide 3D pressure images, maximum mean pressure, and peak pressure in each subregion of the foot for shoe-foot interaction analyses. Essentially, football

shoes with lower plantar pressure peaks will be deemed more desirable for high performance because it is linked to more comfortable and protective load distribution across the foot (Silva et al., 2017). In addition to the magnitude of pressure, plantar pressure distribution analyses may be used to assess performance based on shoe-surface interaction. A soccer player is only able to accelerate quickly and execute explosive cuts and turns if their soccer cleats provide sufficient grip on the turf surface. The pedar® system provides insight into player performance with contact time, contact area, and force-time integral (impulse) of the shoe-foot system against the turf surface. Therefore, plantar pressure data showing load distribution indicated by pressure peaks and speed suggested by contact and impulse may be used to evaluate soccer cleat performance in an objective way, as detailed in Section II.

## **Section II: Sex-Based Differences in Plantar Pressure Distribution**

### **Research Question**

How does plantar pressure distribution, measured by force-time integral, differ between males and females for cutting and sprinting tasks?

### *Overview*

The second section of this thesis focuses on an Institutional Review Board-approved laboratory study with female and male soccer athletes at the Bowerman Sports Science Center in Eugene, Oregon.

In response to the limited attention towards female data for female-centric soccer cleats, the Bowerman Sports Science Center heavily emphasized having both female and male subjects to investigate sex differences that may inform design. Females have different anthropometrics (including height and weight), anatomical alignment, movement patterns, and playing behaviors than males (Kulesa et al., 2017). When performing sudden cutting movements, females tend to have less hip flexion and more hip external rotation than males (Althoff & Hennig, 2013). Some movement differences are due to anatomy, while others are due to training. Movement differences between males and females influence plantar pressure distribution. For example, in a cross-over cutting task in hard ground cleats, males demonstrated increased force in the lateral midfoot and forefoot compared to females (Sims et al., 2008).

Moreover, females may tend to have lower traction demands than males due to relatively lower leg muscle strength and different neuromuscular control techniques when cutting (Althoff & Hennig, 2014). Lower performance and higher injury risk are some of the consequences of

female soccer players wearing the currently available cleats that are sold to them without their specific needs in mind.

This data collection is part of a larger soccer cleat study for Emily Karolidis's PhD in Biomechanics dissertation at the Bowerman Sports Science Center (BSSC) at the University of Oregon in Eugene, OR. From September 2022 to June 2024, I served as an undergraduate research assistant on Emily's "Cleat Crew" advised by Human Physiology professor and BSSC director, Mike Hahn. This study investigates male and females' lower-extremity responses to soccer cleat stud shape adaptations and systemic fatigue while performing dynamic cutting and sprinting tasks.

The University of Oregon Institutional Review Board approved data collection on human subjects for this study. Selected soccer athletes provided informed consent to participate. Motion capture and plantar pressure data collection occurred at UO Athletics facilities in Eugene, OR. Each data collection was divided into three main parts: pre-fatigue sport-specific sprint stops and cuts at the Marcus Mariota Sports Performance Center, a modified Gauntlet fatigue protocol at the Moshofsky Center, and post-fatigue sport-specific sprint stops and cuts back at the Marcus Mariota Sports Performance Center. For my thesis, I analyzed the plantar pressure data gathered during part of the fatigue protocol in the 400 m segment.

## **Methods**

### *Participants*

Ten male and ten female soccer athletes were recruited for this study. Selected athletes were aged 18-26, actively played or trained at least once per week for soccer, had no lower extremity injury in the past year, and had no history of anterior cruciate ligament injury. Athletes

wore men’s shoe size 10-11 or women’s 8-9 (+/- half a size) to participate in the study.

Participant anthropometrics, including shoe size, height, and weight, were self-reported.

Demographics are charted in Table 1.

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20
Sex	M	F	M	F	M	F	F	M	M	F	M	M	M	F	F	F	M	F	M	F
Age	24	24	22	19	23	21	19	25	22	21	21	25	18	19	20	20	19	18	21	20
Mass (kg)	62	68	72	59	74	57.6	50.8	82.6	77.1	72.5	81.6	70.4	56.1	65.9	72	58.9	72.6	56.7	81.6	59
Height (cm)	170	163	175	160	178	168	163	185	175	160	178	175	170	173	173	160	173	165	185	165

Table 1: BSSC Participant Demographics

Sex, age, self-reported mass, and height for 10 males and 10 female athletes. The average male was 22 years old, weighed 73.0 kg, and stood 176 cm tall. The average female was 20 years old, weighed 62.0 kg, and stood 137 cm tall.

## *Footwear Conditions*



Figure 2: adidas Predator Edge 2.0 FG soccer cleat

Firm ground soccer cleat with 12 bladed studs, a coated textile upper with rubber ribbing, and mid-cut collar.

The athlete wore the adidas Predator Edge.2 firm ground (FG) cleat with 12 bladed studs depicted in Figure 2. The bladed cleat has laces, a coated textile upper with Zone Skin rubber ribs for boot-to-ball control, an elastic mid-cut collar, and a thermoplastic polyurethane (TPU) outsole. In general, cleated footwear may have bladed studs, elliptical or conical studs, or a hybrid of both on the outsole. Bladed studs have an overall geometric shape, while elliptical studs are relatively rounded. Hybrid outsole patterns combine the benefits of each type of stud. A systematic study by Silva et al. (2017) noted that bladed studs may improve performance during cuts in natural and synthetic grass when compared to elliptical studs. The tradeoff is that bladed studs are associated with higher risk of lower extremity injury due to higher pressure on the side of the foot when compared to elliptical studs (Silva et al., 2017). Bladed stud shapes are common across cleats designed for high-speed performance needs.

### *Surface Conditions*

Athletes were observed wearing the FG cleats on FieldTurf Vertex CORE artificial turf surface at the Moshofsky Center. Although FG cleats are technically meant to be worn on natural grass, they are the most common soccer footwear choice because they are versatile on both natural and artificial surfaces. Natural grass is the preferred playing surface for high-level soccer, but it is not feasible for many programs to maintain. Professional performance coach formerly with the USWNT and presently with the Washington Spirit, Dawn Scott, inquires, “does the player have the luxury or the fortune to change or have multiple soccer cleats so that they can change and have the optimal cleat for the right surface?” (Pfeiffer & Scott, n.d.). Many professional and pre-professional players are accustomed to wearing their firm ground (FG) cleats on artificial turf because they are more versatile on both surfaces than artificial grass (AG) shoes and more cost effective to only own one pair of shoes.

### *Fatigue Protocol*

The athlete was instructed on how to perform the fatigue protocol upon arrival at the Moshofsky Center. A Garmin heart rate monitoring watch and synced chest strap were worn by the athlete to track fatigue progression. First, the athlete completed a guided warm-up consisting of five minutes of light jogging, 2 x 10 hamstring sweeps, 2 x 10 lateral hops, 2 x 50 m at 75% speed and at 90% speed. Then, the pedar® plantar pressure distribution insoles were inserted into the shoe to replace the sock liner. A belt with the sensor data collection system, SD card, and Bluetooth adapter was worn by the athlete. Sensors were calibrated by the principal investigator controlling the novel database with real-time visuals of plantar pressure distribution in the right and left insole. Next, the athlete completed the last of the warm-up with one 50 m sprint at 100%

speed. Athletes were then given instructions on how to complete the fatigue protocol. The Gauntlet Test is a validated method of assessing cardiorespiratory fitness and aerobic endurance performance; it consists of five stages of running (1600 m, 800 m, 400 m, 200 m, and 100 m) in the least amount of time separated by one-minute rests (Burnsed-Torres et al., 2022). The fatigue protocol is adapted from the Gauntlet Test to simulate soccer-specific movements. The modified fatigue protocol was limited by the football field markings and consisted of running and periodic cuts every ten yards for five stages (1607 m, 799 m, 401 m, 208 m, and 100 m) at vigorous intensity levels separated by one-minute rest periods. Figure 3 shows the fatigue protocol route on the full-size artificial turf field at the Moshofsky Center. Figure 4 shows the fatigue protocol route used on half of the field when shared facility space was limited.

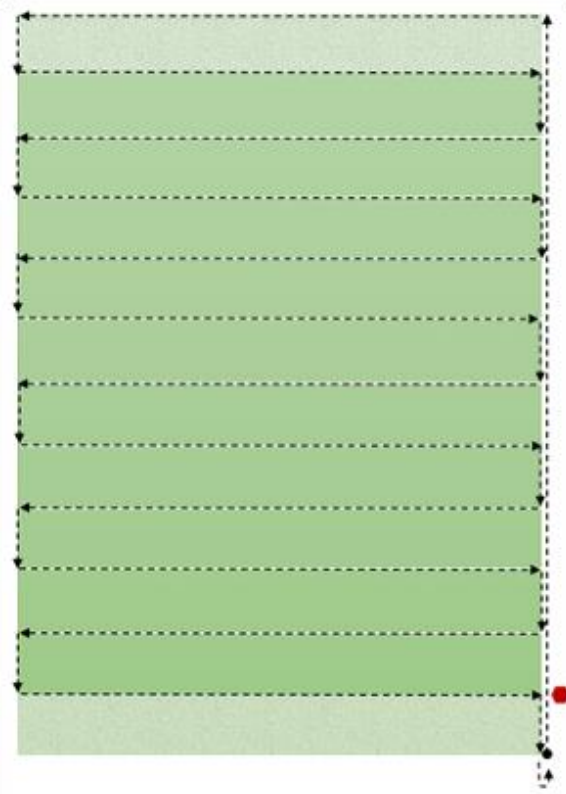


Figure 3: Third stage 400 m route of the fatigue protocol with cuts every 10 yards on artificial turf  
Starting at the back of the endzone, the athlete is instructed to run the length of the field, cut in the back of the opposite endzone, run the width of the field, cut, run 10 yards, cut, and repeat the widths and cuts until the stopping point indicated by the research assistants on the 40-yard line of the opposite end of the field from the start.

Modified 1600 (1607.6 m) on half-field

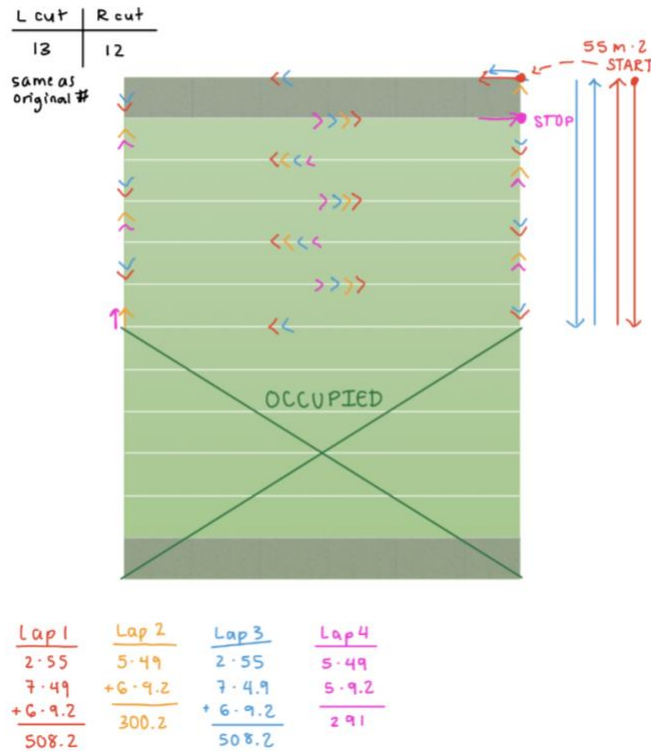


Figure 4: Half-field fatigue protocol modification

One of my roles as a research assistant was to add on to the methodology by calculating a half-field route with the same number of cuts as the original full-field route for the days where we were sharing the Moshofsky Center with other UO Athletics teams.

### Data Processing and Analysis

Plantar pressure data collected via sensors in the pedar® insoles during the 400 m were used to calculate force-time integral (FTI) normalized to body weight in nine regions of the foot using a mask in novel projects®. All cutting steps and the last six running steps in the were identified in the novel emed® system. Figure 5 displays the features that are initially available in the novel emed® system, including individual steps and color-coded peak pressure areas. It also shows a slight stutter step where peak pressure decreases just before the right foot plants hard to make a cut towards the left direction. At some points during data collection, the sensors in the

insoles recorded unnecessary noise before and after individual steps, which was carefully trimmed in novel emed® during processing. After cut and step identification, data were divided into nine foot regions using the percentage masking feature in novel projects®, shown in Figure 6. The heel, medial midfoot, lateral midfoot, medial forefoot, middle forefoot, lateral forefoot, hallux, and the lesser toes are the nine foot regions with sensors that are averaged and mapped onto a color-coded pressure data visual of a left and right foot. In novel projects®, the plantar pressure parameters that will be extracted for each athlete are 3D pressure images showing contact area, maximum mean pressure, peak pressure, and force-time integral (impulse). Figure 7 shows a basic 3D pressure picture from novel projects® for athlete 20 during the 400 m.

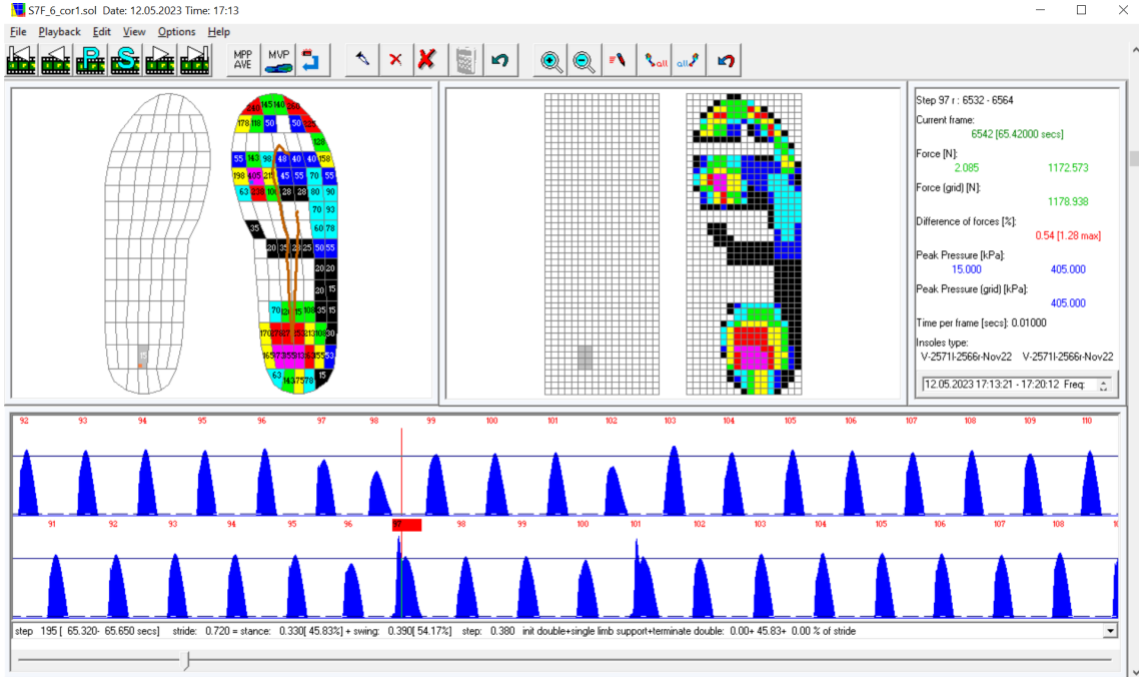


Figure 5: Typical layout of the novel emed® system

Plantar pressure data featuring individual steps and pressure graphs on the bottom, a live color-coded pressure picture of each foot on the top, and quantities like time and pressure on the side. This image depicts a right foot plant before a cut in the left direction.

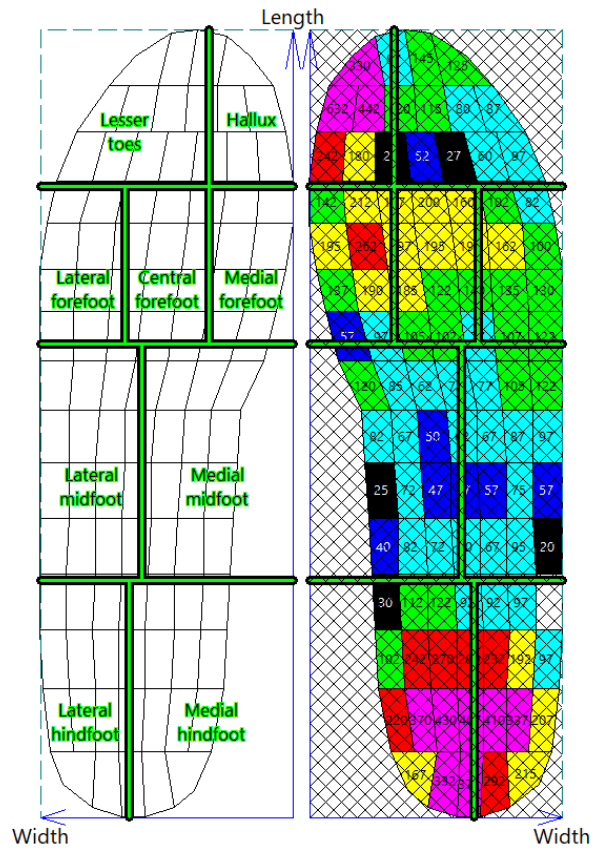


Figure 6: Female right foot masked into nine regions in novel projects®

Plantar pressure data masked in nine regions: medial hindfoot (MH), lateral hindfoot (LH), medial midfoot (MM), lateral midfoot (LM), medial forefoot (MF), central forefoot (CF), lateral forefoot (LF), hallux (HA), and lesser toes (LT).

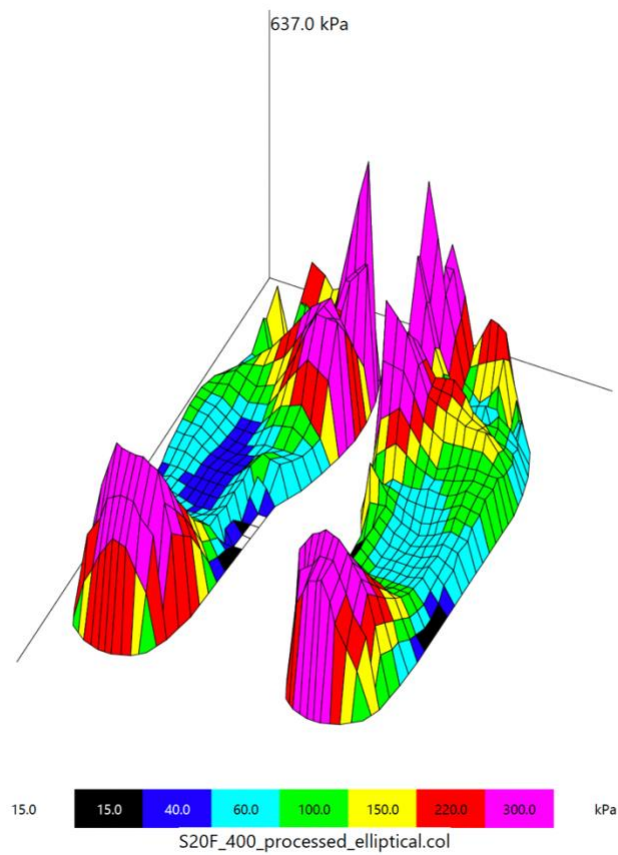


Figure 7: Example 3D pressure picture

Plantar pressure visualization extracted from novel projects® for subject 20 during the 400 m part of the fatigue protocol.

Statistical analyses were conducted in Microsoft Excel and Jamovi (Version 2.53.0) to look at sex differences and plantar pressure distribution. Independent t-tests were used with an alpha level of 0.05 to determine if sex had a significant effect on force time integral (FTI), or impulse, in each region of the foot.

## Results

During cutting maneuvers, females had a significantly lower FTI in the medial forefoot ( $p = 0.029$ ) and significantly higher FTI in the central forefoot compared to males ( $p = 0.006$ ) (Figure 8).

While running straight, females had a significantly lower FTI in the medial forefoot ( $p = 0.016$ ) and lesser toes ( $p = 0.002$ ) than males, while females had significantly higher FTI in the medial hindfoot ( $p = 0.008$ ), lateral hindfoot ( $p = 0.002$ ), and medial midfoot ( $p = 0.007$ ) than males (Figure 9).

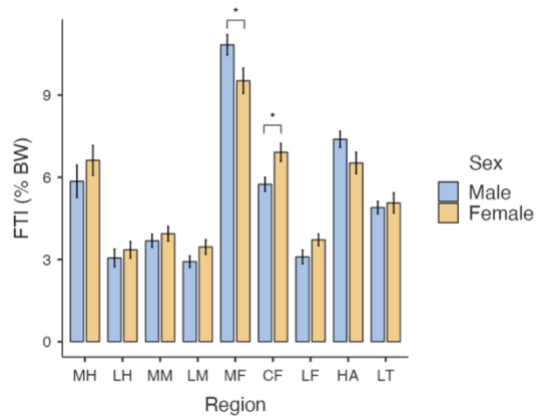


Figure 8a: Side-cutting mean FTI in each foot region for each sex with significant difference indicated with stars ( $p < 0.05$ )

Significant differences in mean FTI across sexes occur in MF and CF ( $p < 0.05$ ), where FTI is higher for males in the MF and higher for females in the CF.

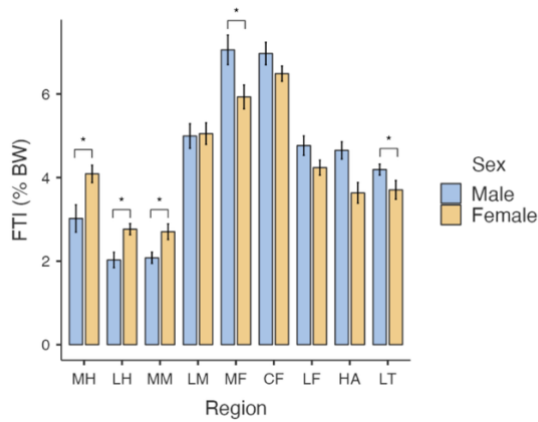


Figure 9: Straight running mean FTI in each foot region for each sex with significant difference indicated with stars ( $p < 0.05$ )

Running mean FTI in each foot region for each sex with significant differences in MH, LH, MM, MF, and LT ( $p < 0.05$ ).

## **Discussion**

As a whole, results from Bowerman Sports Science Center's fatigue protocol with straight running and cutting maneuvers align with previous soccer-specific literature suggesting that FTI during straight running is highest in the MF, CF, HA, and lesser toes (Eils et al., 2004; Queen et al., 2007; Sims et al., 2008). The aggregated data also suggests that FTI during cuts for both sexes is generally highest in MF, HA, and MH.

Delving in the sex-specific data, the results oppose the finding from Eils et al. (2004) that male FTI in CF is greater than female FTI in cuts. It is unclear why females in this study cut with greater FTI in the central forefoot than their male counterparts. Results support that male FTI in CF is greater than female FTI in cuts during sprinting (Eils et al., 2004). Figure 10 summarizes FTI data compared across sex overlaid on the foot morphology graphic from Figure 1.

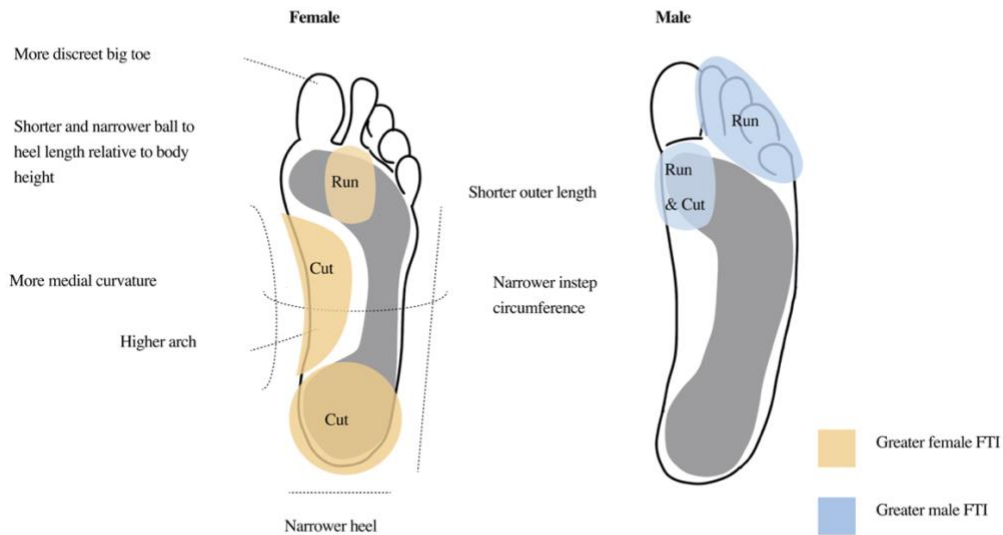


Figure 10: Summary of FTI differences in running and cutting, as well as general foot morphology differences

On the female foot, yellow zones are where FTI was significantly greater for female athletes than males. On the male foot, blue zones are where FTI was significantly greater for males than females. Text overlaid on the colors indicate the type of task where the plantar pressure distribution differed across sex.

It is unclear why female FTI in the hindfoot is greater than in male FTI. It should be investigated if heel striking is a form of adapting to fatigue or to the fit of the cleat since heel striking can be undesirable for increased load on the knee.

Keeping in mind the limited published studies on the impact of soccer cleat design on female performance during soccer-specific tasks, the study at the BSSC will be a helpful contribution to objective biomechanics literature. In addition to examining sex differences, the BSSC study is unique because it tests plantar pressure distribution when a soccer player is in a naturally fatigued state, mimicking what may be experienced over the course of a match or

training. Other studies mentioned in the literature review in section two are based on shorter task scenarios where fatigue is less likely to be achieved.

However, this study was limited in the sense that it did not generate any subjective data. If the study were to be reimagined, it would be helpful to include a survey opportunity for athletes to rate how they felt in all stages of wearing, performing, and removing the different bladed versus elliptical cleats immediately after performing the fatigue protocol. Additionally, in future iterations of the athletes should be instructed to complete the task in a certain amount of time—perhaps based on their baseline range—since speed affects FTI.

These initial quantitative sex-based insights on plantar pressure distribution during running and cutting may be applied to product design that modifies load distribution in section three. Nonetheless, more biomechanics and qualitative perception-based research is needed to confirm what outsole, insole, and upper accommodate female athlete needs.

## Section III: Design Research and Concept Development

### Research Question

How might we empower female soccer athlete performance by building trust in supportive gear?

### *Overview*

I aim for my emerging design practice to be centered around the concept of design justice, “an approach to design that is led by marginalized communities and that aims explicitly to challenge, rather than reproduce, structural inequalities” (Costanza-Chock, 2020). Considering the lack of qualitative human insights from the plantar pressure distribution study at the BSSC in Section II, I now attempt return to female athletes’ voices to the core of the human-centered design process. This third section is driven by ethnographic design research and uncovers pain points and possible solutions for the pre-professional and professional athlete. The target user of the design solution is a female athlete who will champion innovative support gear within her soccer community once trust is established through female athlete-validated performance benefits. Utilizing foot morphology and biomechanical performance differences between female and male soccer players to inform gear design will bring the soccer world one step closer to finally meeting the unique needs of female soccer athletes.

Throughout the process of my thesis, I constantly had to diverge and converge my thoughts and present them in a digestible way for biomechanics, design, and unspecialized audiences. I was instructed to develop a guiding north star in PD 488 BFA Capstone course with

instructors Sean Kelly and Nate Roese. Figure 11 through 13 show the progression of my north star before and after feedback from industry professionals at our midterm review session.

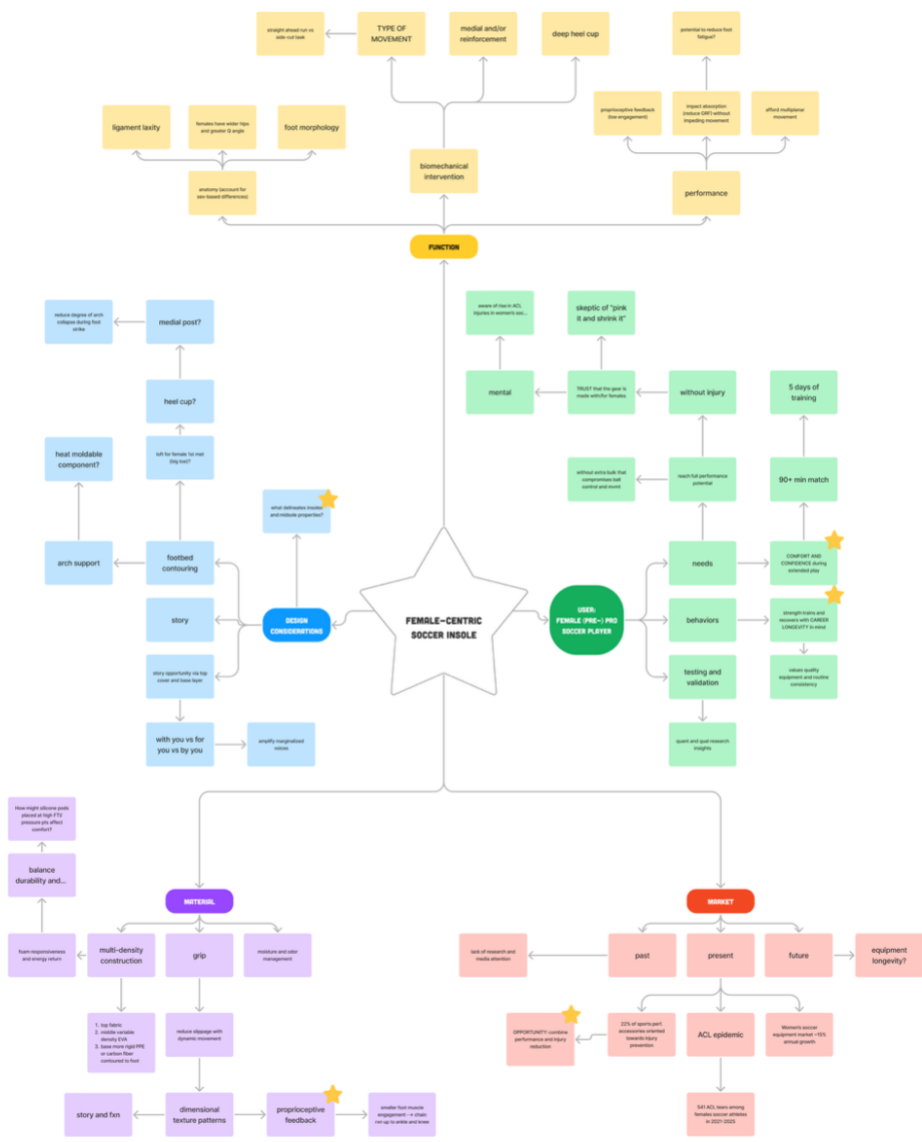


Figure 11: North Star Pre-Midterm Feedback

Five color-coded categories of jobs to be done for my CHC thesis and BFA capstone: function in yellow, user in green, market red, material purple, and design considerations in blue.



Figure 12: North Star During Midterm Feedback Session

Industry professionals helped generate a new project direction focused on trust and player adoption of a product for the rest of the term.



Figure 13: North Star Post-Midterm Feedback

I needed to consolidate words into visuals and design directions for an insole and grip sock.

## Ethnography

Ethnographic research is defined by people and context. It consists of surveys, interviews, immersions, shadowing, focus groups, and observation. To maintain empathy for the user in the process of highly technical research, I conducted an 18-question Qualtrics survey (n=45) to gather qualitative insights on soccer gear usage and selected two volunteer participants for a 30-minute interview each to discuss their soccer journeys.

### *Survey*

A total of 25 females, 18 males, and two people who preferred not to share their pronouns responded to the 18-question Qualtrics survey that I distributed via Instagram, LinkedIn, Reddit (r/bootroom and r/thorns), and the Women in Soccer newsletter. Raw survey data for each participant is shown in Table 2.



ID	Age	Gender	Level	Team	Position	Playing Level	Discomfort	Response	Footwear	Modifications	Other
01-34	34	Male	University	Division III	Forward	2-3 days/week	ankle, knee	Yes, I've reported my experience	Yes, I've reported ankle pain	Yes, I've reported knee pain	Yes, I've reported shin pain
01-35	35	Female	University	Division III	Forward	2-3 days/week	ankle, knee	Yes, I've reported my experience	Yes, I've reported ankle pain	Yes, I've reported knee pain	Yes, I've reported shin pain
01-36	36	Male	Adult Recreational	Club	Forward	1 day/week	ankle, knee	Yes, I've reported my experience	Yes, I've reported ankle pain	Yes, I've reported knee pain	Yes, I've reported shin pain
01-37	37	Female	Adult Recreational	Club	Forward	1 day/week	ankle, knee	Yes, I've reported my experience	Yes, I've reported ankle pain	Yes, I've reported knee pain	Yes, I've reported shin pain
01-38	38	Male	University	Division III	Forward	2-3 days/week	ankle, knee	Yes, I've reported my experience	Yes, I've reported ankle pain	Yes, I've reported knee pain	Yes, I've reported shin pain
01-39	39	Female	University	Division III	Forward	2-3 days/week	ankle, knee	Yes, I've reported my experience	Yes, I've reported ankle pain	Yes, I've reported knee pain	Yes, I've reported shin pain
01-40	40	Male	Adult Recreational	Club	Forward	1 day/week	ankle, knee	Yes, I've reported my experience	Yes, I've reported ankle pain	Yes, I've reported knee pain	Yes, I've reported shin pain
01-41	41	Female	Adult Recreational	Club	Forward	1 day/week	ankle, knee	Yes, I've reported my experience	Yes, I've reported ankle pain	Yes, I've reported knee pain	Yes, I've reported shin pain
01-42	42	Male	University	Division III	Forward	2-3 days/week	ankle, knee	Yes, I've reported my experience	Yes, I've reported ankle pain	Yes, I've reported knee pain	Yes, I've reported shin pain
01-43	43	Female	University	Division III	Forward	2-3 days/week	ankle, knee	Yes, I've reported my experience	Yes, I've reported ankle pain	Yes, I've reported knee pain	Yes, I've reported shin pain
01-44	44	Male	Adult Recreational	Club	Forward	1 day/week	ankle, knee	Yes, I've reported my experience	Yes, I've reported ankle pain	Yes, I've reported knee pain	Yes, I've reported shin pain
01-45	45	Female	Adult Recreational	Club	Forward	1 day/week	ankle, knee	Yes, I've reported my experience	Yes, I've reported ankle pain	Yes, I've reported knee pain	Yes, I've reported shin pain

Table 2: Qualtrics survey demographics and response data (n=45)

Raw survey data covering demographics, playing levels, discomforts, modifications, and insole insights.

As outlined in the pie chart in Figure 14, the majority of survey respondents played soccer at the university Division I-III or club level (42.2 %) or adult recreational level (31.1 %).

To uncover general physical pain points when playing soccer, participants were asked to report their experience with lower extremity injuries and to rank their top three movements that caused the most discomfort. When asked about lower extremity injuries, 22.7% experienced knee injuries (with 6.9% involving the anterior cruciate ligament or ACL), 20.8 % were affected by ankle injuries, 14.9% experienced foot injuries, 11.9% had shin splints, 9.9% had quad injuries, 8.9% had hamstring injuries, 5.9% felt injury to other lower body parts (hip, plantar fascia, groin, and calf), and 5.0% experienced Achille’s tendon injuries, indicted in Figure 15. The top three movements that caused athletes the most self-reported discomfort were quick

changes in direction (30.1%), quick stopping (23.3%), and sprinting (9.6%), summarized in Figure 16.

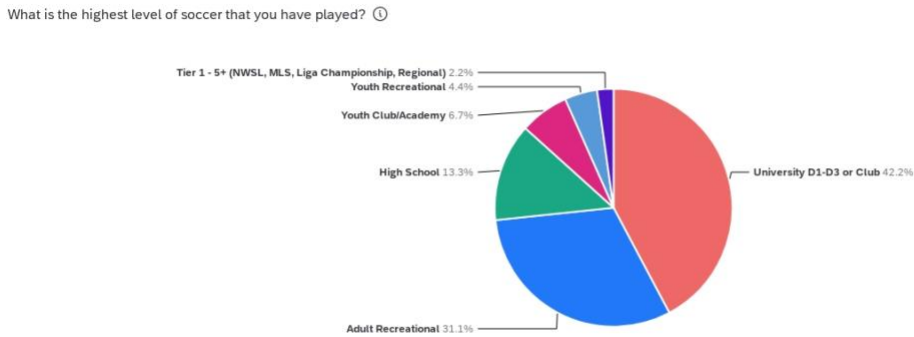


Figure 14: Distribution of participants' highest played levels of soccer (n=45)

At the highest point in their soccer career, 2.2% played Tier 1-5+, 4.4% played youth recreational level, 6.7% played youth club/academy, 13.3% played high school, 31.1% played adult recreational, and 42.2% played university DI-III or club level.

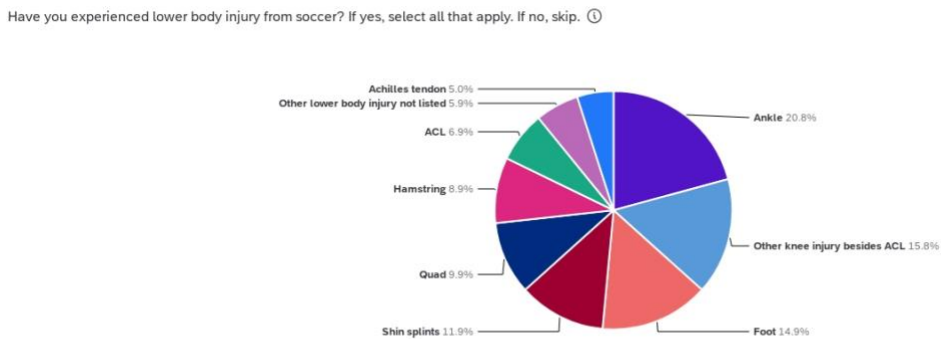


Figure 15: Distribution of participants' lower extremity injuries (n=45)

22.7% experienced knee injuries (with 6.9% involving the ACL), 20.8 % were affected by ankle injuries, 14.9% experienced foot injuries, 11.9% experienced shin splints, 9.9% experienced quad injuries, 8.9% experienced hamstring injuries, 5.9% experienced injury to other lower body parts (hip, plantar fascia, groin, and calf), and 5.0% had Achille's tendon injuries.

What movements cause you the most discomfort? Choose 1-3. ①

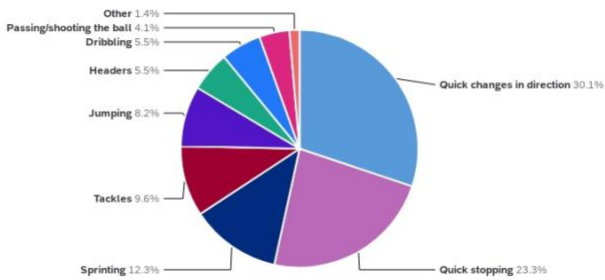


Figure 16: Ranking of movements causing the most discomfort among subjects (n=45).

The top three movements that caused athletes the most self-reported discomfort were quick changes in direction (30.1%), quick stopping (23.3%), and sprinting (9.6%).

To uncover what footwear modifications players were using to adapt to foot discomfort, survey participants were asked if they had ever replaced the insoles in their soccer cleats, and if yes, they were asked to specify the replacement insole. Interestingly, in Figure 17, 37.5% of athletes reported replacing their insoles. Among those who had replaced their insoles, two people tried CURREX CLEATPRO™, one tried Sorbothane double strike and replaced it every 6 months, two tried the Superfeet Green, one tried an unspecified Superfeet model, one tried Superfeet Carbon and replaced it maybe every two years, one used the Oupower Under Armour Charged insole and replaced it annually, one person swapped their factory inserts for skateboard insoles, another person added unspecified arch supports to prevent plantar fasciitis,” and others used unspecified replacements. The survey finding that over 2/3 of athletes replaced their insoles is more than expected. When I asked several players in person about whether they or anyone they played with used foot orthotics in their boots, it seemed that the modification was quite rare. Perhaps future iterations of this survey should specify whether the athletes who replaced their insoles kept them as a permanent part of their routine or only tried them as a temporary solution.

To assess the opportunity for insoles to play a role in easing player discomfort, I noted that 60.0% of respondents would consider replacing their insoles if they hadn't already. Furthermore, Figure 18 demonstrates that 56% of respondents would want their insoles comfort and cushioning to improve, 26% would like to see enhancements to the insole's fit in the shoe, and 15% would like to see improvements to the insole's odor management properties.

Have you ever replaced the insoles in your soccer footwear? ⓘ

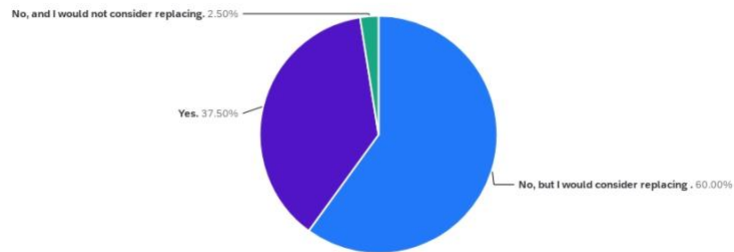


Figure 17: Distribution of players who have replaced their insoles, considered replacing them, or do not intend to replace them

Over 1/3 (37.5%) of respondents have replaced their insoles in their soccer footwear, 60.0% have not but would consider doing so, and 2.5% have not and would not consider doing so.

If you could improve anything about your soccer insoles, what would you improve? ①

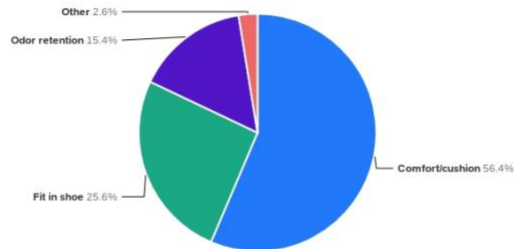


Figure 18: Desired insole improvements

The majority (56.4 %) of soccer players in the survey (n=45) desire improvements to be made to the comfort/cushion of their insoles.

If I were to reiterate this Qualtrics survey, I would ask players to identify what areas of the body they most frequently experienced pain when performing quick changes in direction, quick stops, and sprints. In particular, I was curious to identify where players experienced the most discomfort, whether it be in the medial side, lateral side, heel, plantar (bottom) side, or dorsal (top) side of the foot. To fill in the gap of knowledge left by the survey, I explored more literature reports. The results of a physical performance and perception of discomfort study with male athletes in two different conditions boot (leather with bladed studs and synthetic with elliptical studs) by Kryger et al. (2021) showed that athletes tended to experience more dorsal and plantar discomfort than in other regions of the foot when performing a match simulation. The boot with bladed studs had demonstrated significantly higher plantar pressures in the heel and 1st and 5th metatarsal (MT) regions during sprinting, side cutting and cross cutting movements compared to the boot with elliptical studs. The study suggested a relationship between increased foot discomfort, decrease in power generation, and decrease in player

intensity level (Kryger et al., 2021). The findings on discomfort present an opportunity to design a gear solution that promotes player comfort and enables high-level playing performance.

Ultimately, the broad survey data (n=45) reveals that ankle, knee, and foot injuries are quite common; quick changes in direction, quick stopping, and sprinting cause the most discomfort out of a given list of common soccer movements; and that most athletes (60.0%) have not replaced the factory inserts in their football boots, but that they would consider doing so. The survey highlights an opportunity for soccer cleat insoles to be improved in the areas of comfort and cushioning, fit within the shoe (i.e. secure fit to reduce slipping), and odor management.

### *Athlete Interviews*

After gathering the broad quantitative data from the Qualtrics survey, I attempted to focus on the female pre-professional and professional qualitative insights through interviews and observational research with two female soccer athletes.

### *DT's Semi-Pro Journey with ACL Injury*

The first female athlete interviewee is a 28-year-old semi-professional and former DII collegiate soccer player, whose name will be referred to under the pseudonym DT. DT typically plays center forward or center midfielder in her semi-professional tournaments that vary in frequency depending on her availability. In college, DT balanced a strong academic and athletic profile because she was not sure if she would turn pro. In between college seasons, she tried out for the Houston Dash and Western New York Flash in the National Women's Soccer League.

Unfortunately, at the beginning of her junior season, she tore her ACL (one of a pair of ligaments running deep diagonally in the middle of the knee, connecting the femur to the tibia). In the same

season, DT underwent an ACL reconstruction surgery that negatively impacted her NCAA Eligibility and her plans to finish nursing school with her best friend.

“You have this plan of your life, and then this one injury happens. It just snowballed, like one thing after another. The life planning aspect was really tough, and at the end of it, it was just like, I have to keep going.”

DT was determined to return to the sport as quickly as possible and maintained a strong relationship with her college team’s strength and conditioning coach to rehabilitate her knee.

“I would spend hours rehabbing every single day. Whether that's like on the treadmill, on doing whatever knee exercise rehab, the amount of single leg squats I've done, I have no clue..., I also did stuff outside of the weight room: sprinting and cutting and working on that, because I felt like that's how I tore my ACL--planting and turning. Cutting is what I was really afraid of. It really messes with your mind if you don't want to tear it in the same way.”

Upon returning to play in her senior year, DT’s doctor required her to wear a DonJoy knee brace like the one shown in Figure 19, but it caused a lot of chafing. DT recalled “It didn’t fit right. My skin was going raw.”



Figure 19: An athlete wearing a DonJoy knee brace (DonJoy®, 2023)

The DonJoy knee brace has a four-point-hinge, silicone and foam condyle pads, adjustable straps, and a moisture wicking liner.

DT has since graduated from college (and from her knee brace) and competes at the semi-pro WPSL and UWL levels wearing a combination of grip socks, ankle braces, turf shoes, and cleats. When asked about what qualms she had with existing products, DT noted that soccer shirts marketed with women’s fit are inaccurate, shown in Figure 20.

“I think it's weird that there's like a woman's cut at least, like with the torso, there's woman cut tops, because I feel like no soccer player, or very little soccer players are actually built like an hour class figure.”



Figure 20: DT playing for Angelo State University

DT disliked the tight hourglass fit of women's jerseys that did not accurately represent the diverse body shapes of female athletes.

Additionally, DT said that TRUsox® grip socks with silicone on both the interior and exterior of the sock are a recent addition to her kit. She thinks that other grip socks with silicone only on the exterior might lead to dangerous foot fixation.

“I recently got into grip socks...I tried a couple brands, like Amazon brands, and then, the TRUsox®. The Amazon brands, at least the ones that only have silicone rubber on the outside, remind me of hospital socks. I think [the Amazon branded socks] are actually more dangerous because I feel like your sock will stay so if you don't have any grip, you're probably gonna slide in your shoe, and your socks going to go with you...Your foot and body will go anywhere else.”

DT has become reliant on her grip socks. She was not allowed to wear them at a recent semi-pro soccer tournament because they were not part of the official team uniform that required full length solid color socks. Consequently, DT experienced blisters on her big toe, balls of her feet, and on the tops of her foot because of frequent cutting movements. She narrated, “I wish that

was preventable.” DT recently finished her Master of Science in Sports Product Management at the University of Oregon. She continues to play in soccer tournaments and recreational leagues while working part-time as a travel nurse.

### *SG’s Pre-Professional Journey with Ankle Injuries*

The second female athlete interviewee is a current 20-year-old DIII collegiate soccer player and a prospective player for the Cambodian Women’s national team. She will be referred to as SG. SG typically plays center mid or outside midfielder. During the peak of the season, she experiences 2-5 hours of soccer training and matches 6-7 days per week. Since high school, SG has experienced weak ankles that are prone to rolling. She has made modifications to her kit for both confidence, performance, and injury prevention benefits. During our interview, SG showed me the layout of her team’s locker room where her gear is stored, shown in Figure 21.



Figure 21: SG clearing out her gear in the Pacific University locker room in Forest Grove, OR

SG and I conducted part of our interview and concept validation at this location.

SG’s pre-game routine consists of eating apple sauce followed by a chewing a piece of gum—even during the game—to focus. It’s important for SG to feel cool when she is playing so that she moves more confidently. Part of feeling cool and prepared involves tucking in her shirt sleeves, tucking in one short, and pulling up her socks as high as she can. SG described,

“A lot of times, subconsciously, I tuck one of my shorts on one side into my spandex. When I feel like I’m really in it in the game, I go like [gestures]. It makes me feel like I’m really cool. But feeling cool is what makes me feel more confident and play better. Yeah, I have to feel cool.”

Ill-fitting team-issued gear is one pain point that can get in the way of SG feeling cool when she plays. She has consistently worn ankle braces on both sides as a preventative measure, but they

hardly fit in her cleats. Luckily, SG hasn't rolled her ankles again in the past year, yet she notes that soon after rolling her ankles, she is more hesitant to go in for tackles.

Figure 22 shows SG adjusting her boots at the start of a match. Figure 23 shows how the boot collar on SG's Nike Phantom GX cleats expanded because of the wide ankle braces. SG noted, "It's extremely hard to find cleats that don't give blisters in the heat." Her insoles in the same figure show signs of wear in the first metatarsal, ball of the foot, and heels, areas where blistering occurred. SG thinks that the stiffness of team-issued socks contributes to blisters and calf cramping. Stiff socks frustrate SG and her teammates for various reasons.

"I wish they were stretchier—especially for the girls that are tall on my team. I don't have to deal with this but for Raya, it'll go to her upper shin, and she's, like, 'Guys, this is ridiculous. Like, I shouldn't have to be dealing with this.' Since they're so stiff, they're tight and they give us calf cramps. That's when people start to cut the backs of their socks ... I just feel like I need to pull stuff up. And so, when my socks are so stiff and they go so low, I hate it. It irks me."

Similar to the first interviewee, DT, SG also is displeased with the soccer apparel design world's attempt at women's top fit. SG says,

"I personally don't really care for the whole woman fit top. I'd much rather have like, a boxy t-shirt or shirt like the men do rather than tightly fitted shirt because all women don't have the same body. The fact that they're making shirts like that, like especially for soccer players, we definitely don't got that. Yeah, it's just tight. Yeah, it's just uncomfortably tight."

SG and I concluded our interview on this topic of ill-fitting gear. We agreed to meet again weeks later to test an insole concept while performing low-risk movements.



Figure 22: SG adjusting her cleats and ankle brace

SG notes that her ankle braces stretch the boot collar, but she wears them to prevent rolling her ankles.



Figure 23: SG's Nike Phantom GX cleats and insoles worn for a bit over one year

Insoles (top) show wear in the big toe, ball of the foot, and heel. Cleat shoes widening in the boot color from movement with the addition of ankle braces.

### *Insights on Gear Usage, Behaviors, & Modifications*

Athletes can play at their highest potential when they can trust that their gear will support all the dynamic movements that soccer demands. Additional research can be done to understand how female athletes develop trust in their gear. The best indicator that an athlete trusts their gear is when they continue to buy the same model repeatedly. I learned that DT is a data-conscious adopter of new gear; she will research product reviews online and decipher possible biomechanical risks using her nursing career knowledge. DT gets frustrated by how quickly soccer footwear models rotate. She says that once she finds a pair of cleats that work well for her, she wants to purchase them again; however, by the time she is ready to replace an old pair of cleats, that previous pair is nowhere to be found on the market. SG is a community-oriented adopter of new gear; she relies on insights from her teammates and peers when deciding the next pair of cleats to buy. Many of SG's teammates wear grip socks, but she noted that it is a cost barrier for her to switch out her current crew socks.

When a player is injured, they are unable to make progress towards their performance goals. The pre-professional and professional female soccer athletes that I interviewed are very aware of potential injuries and modify their kit to mitigate the risk of cutting their playing season short. Unfortunately, some gear that is designed for injury prevention can impede performance. For example, DT's DonJoy knee brace was frustrating for her to wear while playing because it caused chaffing and cuts on her leg. SG's ankle braces expanded the collar of her cleats. Even though orthotics like knee braces and ankle braces might be incompatible with the form and fit of existing team-issued gear, DT and SG still wear these items for protective measures.

Both athletes experienced pain points in their journey during knee and ankle injury rehabilitation. DT underwent hours of physical therapy to restrengthen muscles and practiced performing planting and cutting movements safely to rebuild her confidence in her knee ACL when returning to play. SG did not have time to go to physical therapy to rehabilitate her ankle with the athletic trainer in college, so she adjusted her equipment set to include ankle braces all of the time. SG is headed into her senior season of college and is determined to choose the proper gear to allow her to play the full season without injury. SG even asked me to recommend a few cleats. Figure 24 shows SG playing in a match with her socks rolled high and ankle braces fitted.



Figure 24: SG playing in a match for Pacific University vs. George Fox University

SG wears her ankle braces atop her team-issued socks.

Both interviewed athletes demonstrated a willingness to try new orthotics and gear that would boost their confidence on the field and alleviate their frustrations with blisters, tight shirts, and tight socks. Neither athlete had previously tried using an insole to help with knee-ankle

stability, nor foot comfort, but both demonstrated that they would be open to try a soccer cleat insole or sock supported with athlete research insights.

### **Video Analyses: Moment of ACL Injury**

Between 2022-2025, at least 541 ACL tears were reported among female athletes according to the ACL Women Football Club. On a personal note, I have torn both of my ACLs in the span of seven years from 2018-2025 through playing soccer. The ACL reconstruction surgery and rehabilitation process to return to sport is lengthy. It is both physically challenging to complete physical therapy exercise to restrengthen the quadriceps and ACL, and mentally challenging to watch healthy teammates continue the season. Injured athletes like interviewee DT and myself miss out on 6-12 months of valuable time to perform and enjoy the sport.

Keeping in mind the statistic that female athletes are 2-3 times more likely to tear their ACLs than their male counterparts, I gathered match footage to investigate what mechanics were common across these injuries. I analyzed videos from nine female professional soccer players who were confirmed with ACL injuries in the past five years. The quality of videos to sample was limited because women's sports unfortunately still tend to have lower coverage than men's sports. Nonetheless, I screen captured the moment seconds before and after the injury, shown in Figure 25, to uncover patterns.



Figure 25: Video analysis of nine female athletes at the moment of ACL injury

Five out of the nine athletes experienced overpronation of the ankle at or around the moment where they injured their ACL.

All nine ACL injuries were non-contact, which aligns with the literature statistic that most ACL tears in soccer happen without direct contact to the knee. Five out of the nine athletes experienced possible overpronation, excessive inward turn of the ankle, at or around the moment where they injured their ACL. Figure 26 shows four of the athletes with their knee bent or outstretched and foot in an overpronated, high-stress position. All four athletes were later confirmed to have torn their ACLs by medical staff. In 2022, one of the injured Arsenal athletes pictured, Beth Mead, demonstrated how appalled she was about the disproportionate burden of ACL tears on female athletes after the injury impacted both her and her teammate. Mead stated,

“I think if that happened with a Messi, a Ronaldo, a Griezmann there’s probably going to be a lot more done when those things happen...Unfortunately this has happened to us [Miedema and I] but hopefully it can kick somebody up the arse to go on and start doing something.”

Since Mead, other high-profile athletes have shown their support for research endeavors that specifically inquire the underlying causes of the disproportionate effect of ACL tears on female soccer athletes.



Figure 26: Four moments that lead to confirmed ACL tears

Upper left: Beth Mead’s right foot becomes fixated in an overpronated position while her knee is bent (2022). Upper right: Mary Fowler’s right foot is overpronated and right knee is bent. Slow-motion capture shows her femur slide forward beyond the tibial plane (2025). Bottom left: Leah Williamson’s right leg outstretched and foot overpronated (2023). Bottom right: Vivianne Miedema’s left leg bent upon landing for a kick with her left foot also fixated in the turf and overpronated.

The video analyses suggest that when the ankle is fixed in a high stress overpronated position, the misalignment of the ankle puts additional stress on the rest of the lower extremity, including the knee. In the end, the video analysis of non-contact ACL injuries among professionals highlights the pain point of overpronation and foot fixation in the turf being associated with a risk of ACL tear.

Overpronation is defined as the excessive inward turning of the ankle and flattening of the arch. Podiatrists may recommend more supportive footwear, custom orthotics or exercises to strengthen foot muscle and improve skeletal alignment. Unlike running and walking shoes that

have a relatively large amount of space to expand cushioning and support properties in the midsole, soccer cleat functions are limited to its lack of a midsole and purposeful form fit around the foot for close ball contact. Perhaps an orthotic with arch support, in combination with more favorable neuromuscular training and preventative measures, could help reduce the risk of overpronation and foot fixation in the turf for female athletes who are more prone to ACL tears than their male counterparts.

### **Market Analysis**

Before conducting an in-store market analysis, I examined the construction and wear patterns of used insoles across different sports footwear shown in Figure 27. The level of insole design complexity varied greatly across soccer, running, basketball, and walking shoes. For soccer, the women's Nike Hypervenom, women's Nike Phantom GX, girl's Nike Mercurial, girl's Nike Phantom GT all consisted of a thin (~4 mm) single-density foam insole with a single-layer knit mesh fabric top cover. The Nike soccer insoles lacked any substantial arch support or variations in levels of cushioning, and instead primarily relied on the softness of an open-cell foam. The IDA Rise cleat insole was made of slightly more rigid closed cell foam with slight medial curvature, but it was still simple in form. Meanwhile, the insoles for other sports were more substantial in form and material composition. On the extreme end, the women's Nike Cosmic unity basketball insole had a rigid foam cup extending 3 cm tall above the entire perimeter of the insole, most likely to keep the foot extremely stable during dynamic movements on the hard court. A Nike tennis shoe had very slight medial posting to its simple single-density open-cell foam and mesh top cover composition. An adidas Stella McCartney women's sport style shoe had a slightly more rigid closed cell foam medial post with a higher degree of

curvature. Running insoles varied more in material composition. For example, a 7-year-old pair of Superfeet green low-arch model insoles that I wore in high school running shoes featured a full length high density foam atop a plastic stabilizer cap for more structure from the heel to midfoot. The foam for the Superfeet model maintained a more fitted shape—especially around the heel and arch—with the addition of the stabilizer cap beneath it. A 7-year-old pair of over-the-counter Dr. Scholl's insoles that I used in my high school soccer cleats also featured a plastic stabilizer cap mainly in the midfoot and partially around the heel, as well as gel cushion technology in the forefoot and heel.

In terms of wear patterns, Figure 27 shows that the basic soccer insole is made of a thin open cell foam and top cover that is prone to holes and tears. The bottom left inserts show wear in the toes, medial forefoot (which is an area that the athlete experienced blisters), and heel. The wear patterns present an opportunity for zonal material mapping for variations in cushioning and durability.



Figure 27: Worn insoles from various sports

Top left to right features a 7-year-old used pair of women’s Nike Hypervenom soccer insoles and cleats, a 1 year-old pair of girl’s Nike Mercurial insoles and cleats, a torn 1-year-old used Nike Phantom GT girl’s insole made of blue open cell foam, and a once worn, nearly new IDA Rise pair of insoles and cleats. Bottom left features a 1.5 year old pair of women’s Nike Phantom insoles. Bottom right features a span of insoles from various sports footwear; from left to right: girl’s Nike Phantom GX soccer cleat, girl’s Nike Mercurial soccer cleat, adidas Stella McCartney lifestyle shoe, adidas 4DFWD lifestyle shoe, women’s Nike Hypervenom soccer cleat, Jones & Vining general athletic insole, Superfeet green low arch insole, Dr. Scholl’s athletic insole, and Nike Cosmic Unity basketball shoe.

### *Competitive Products*

To assess what existing product solutions existed for the pain points that soccer athletes experienced with their insoles, I conducted a market analysis of over-the-counter prefabricated insoles that were suggested for soccer footwear by players on the initial survey, Reddit, and

product reviews. Figure 28 shows the raw data gathered from the analysis of comparable market options.

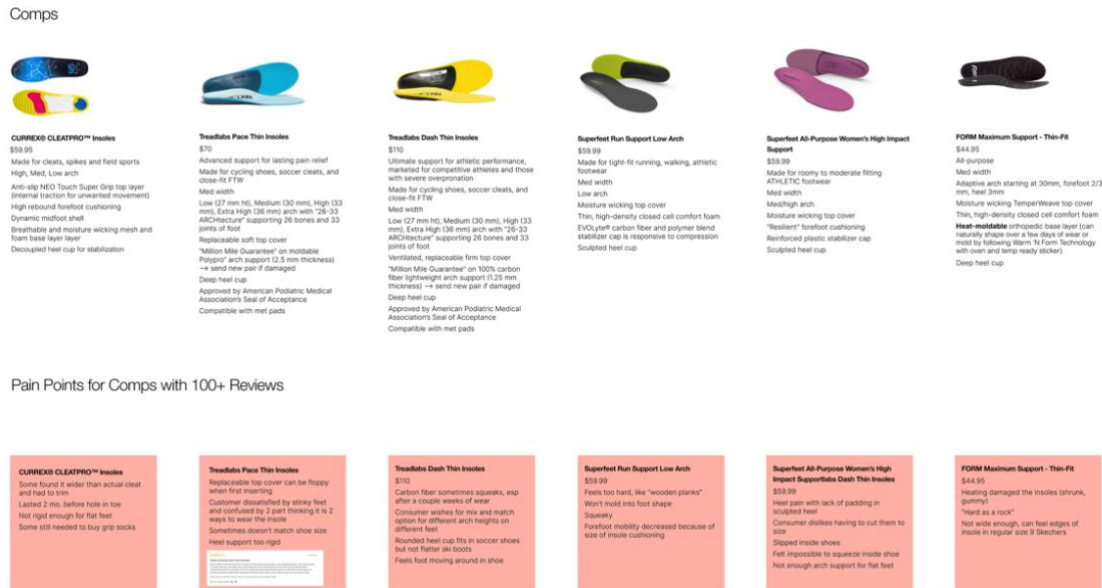


Figure 28: A market comparison of CURREX CLEATPRO™, Treadlabs Pace Thin, Treadlabs Dash Thin, Superfeet Run Support Low Arch, Superfeet All-Purpose Women’s High Impact Support, and FORM Maximum Support-Thin-Fit Insoles

Price points, product features, and pain points indicated in customer reviews for each insole type.

Essentially, only the CURREX CLEATPRO™ and FORM Maximum Support-Thin-Fit insoles were made specifically for soccer cleats. The Treadlabs insoles were originally designed for running shoes and made thinner to fit inside of soccer shoes. Meanwhile the Superfeet green and pink insoles were made for running needs, but fit in athletic footwear with sufficient space. Little to no data could be retrieved on what insoles would work best for female soccer players. Superfeet sells a women’s all-purpose insole that features a sculpted heel cup that might be different than the men’s version; however, product reviewers noted that the Superfeet All-Purpose Women’s High Impact Support “felt impossible to squeeze inside the shoe,” caused heel

pain, slipped inside of the shoe, and lacked enough arch support. In addition to the lack of a female-centric soccer cleat insole, a market gap exists in the region of soccer-specific insoles with elevated technology and materialization, as plotted in Figure 29.

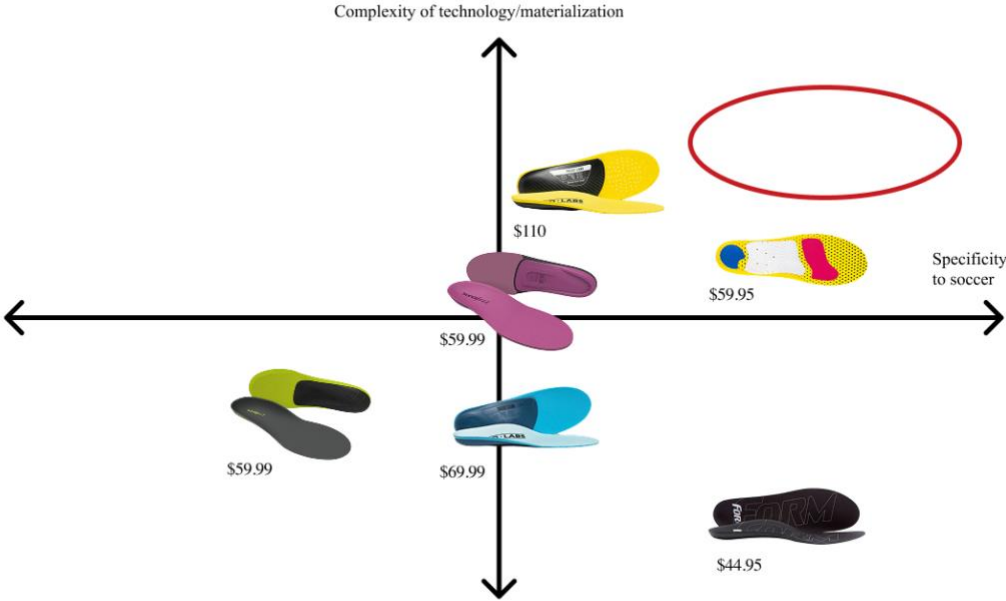


Figure 29: Existing gap in the insole market highlights an opportunity for a female-centric soccer insole

Currently on the market, there is a lack of insoles specific to soccer and complex in terms of technology and materialization.

**Concept Development**

*Problem Statement*

How might we empower female soccer athlete performance by building trust in supportive gear?

### *Functional Success Criteria*

Considering the research insights gathered across section I, II, and III, the success criteria for a solution to the problem statement should achieve the following:

- a) The solution should have compatible fit with the athlete's existing gear.
- b) The solution should provide arch support to minimize the risk of overpronation.
- c) The solution should provide durable comfort for extended wear. For example, the intended athlete may play 2-5 hours/day for 5-6 days/week of training and matches.
- d) The solution should balance the need for slip resistance within the shoe, yet allow for dynamic movement beyond it.

### **Ideation**

Initial ideation sketching exploration included insoles, grip socks, Pilates socks, and other compression and support gear. Keeping in mind the athletes' struggles with knee and ankle stability, as well as the trend in overpronation and foot fixation leading up to ACL injury, I wanted to explore possible orthotic options that provided anatomical support. Figure 30 provides an example of initial ideation sketching.





Figure 31: Low-fidelity clay, foam, and 3d-printed prototypes.

An exploration of foot anatomy and morphology, as well as foam versus plastic material.

### *Mid-Fidelity*

The objective of mid-fidelity prototypes is to start to focus on the proof of concept and details that might be useful for the ultimate solution. The line between low and mid-fidelity prototyping is blurry, but often, form development in computer-aided design (CAD) programs occurs at the mid-fidelity level. Early in my thesis journey in 2023, I experimented with adapting outsole stud lengths by reiterating and adjusting existing cleat models in Figure 32. After gaining experience as an undergraduate researcher in the Bowerman Sports Science Center and talking to biomechanics research and development professionals like Mike Hahn at the BSSC and Emelia Funnell at IDA Sports, I decided that I could not obtain enough data and athlete to justify an entire boot design and outsole. Later in 2025, I turned to orthotics as a possible partial solution to the athletes' needs. Figure 33 is a snapshot of my CAD workspace in Rhino 8, where I built

orthotics of varying lengths based on anatomical locations that I marked on the women's size 8 soccer last.

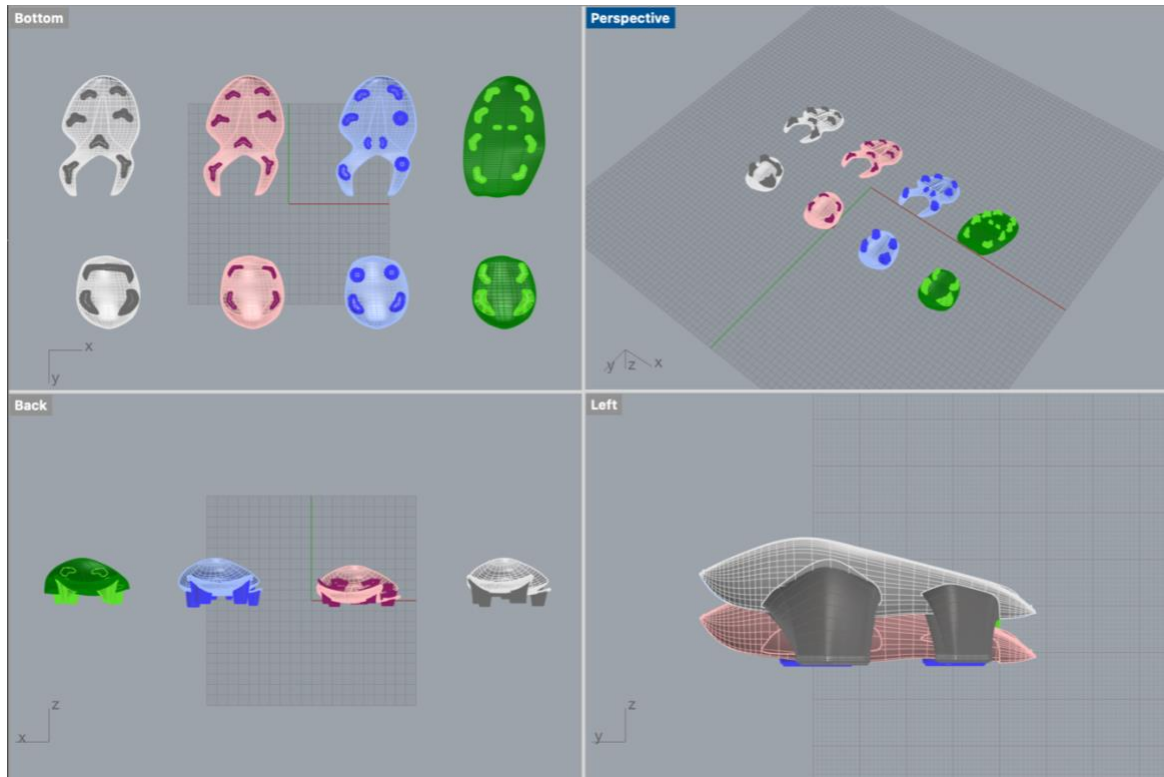


Figure 32: Outsole CAD modeling workspace in Rhino 7

Different iterations of existing outsole plates with modified stud lengths.

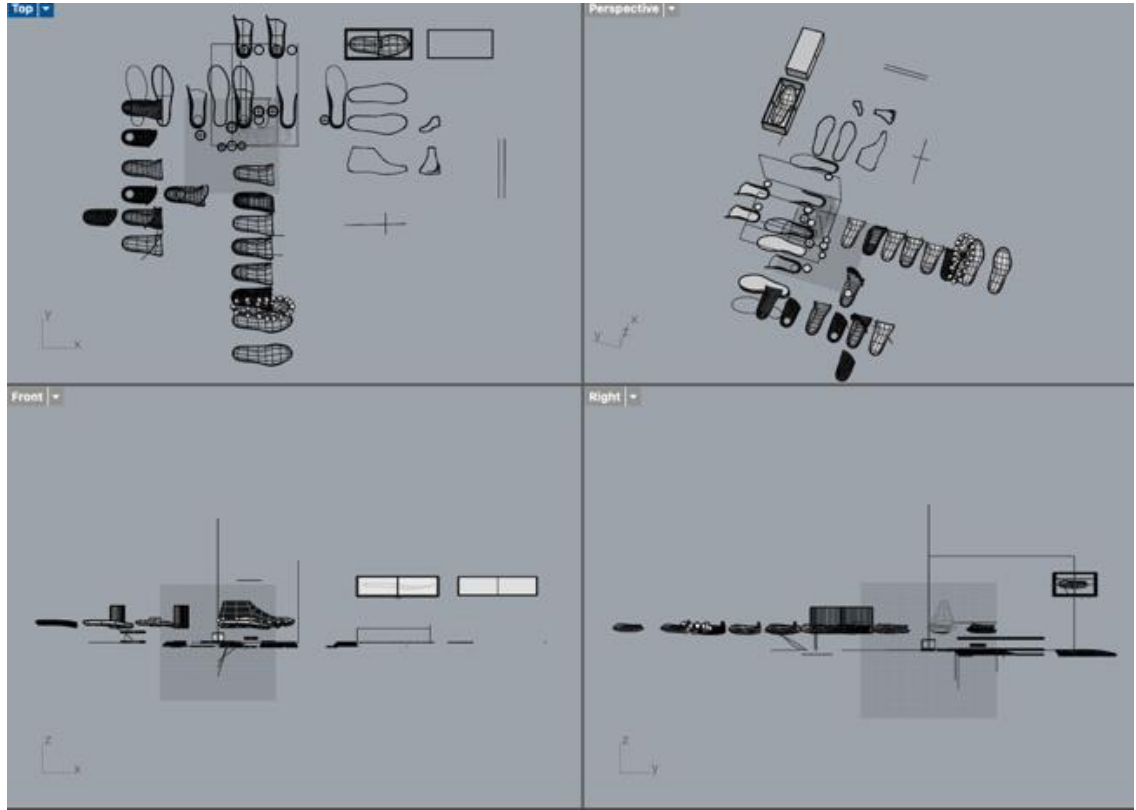


Figure 33: Insole CAD modeling workspace in Rhino 8

Different iterations of MPJ, sulcus, and full-length orthotics drawn in CAD based on a women's size 8 soccer last.

Amidst the CAD modelling and rough prototyping, I became increasingly aware of the popularity of grip socks in soccer after attending a Thorns game and seeing many players wearing them beneath cutoff socks. In my mid-fidelity sketching in Figure 34, I considered a grip sock as a possible solution for in-shoe foot alignment and dynamic arch support to complement the insole's static arch support.

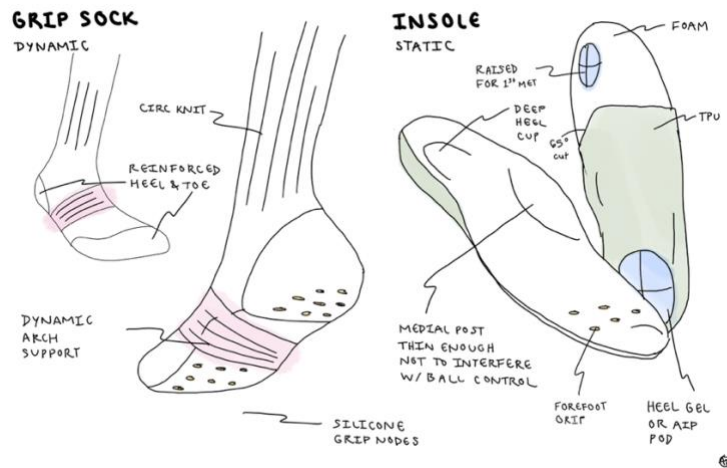


Figure 34: Grip sock and insole concept sketches.

A grip sock might be able to provide dynamic arch support that could help an insole's static arch support for the athlete's foot.

I attempted to pattern and prototype a grip sock, but I could not source knit materials with proper stretch and ventilation. Typically, soccer socks are manufactured with circular knitting machines rather than by a cut and sew technic. Figure 35 is an attempt at patterning a full-length soccer sock, which did not even fit over a last, much less a flexible foot, once sewn because the yellow piqué knit fabric that I did not have enough elasticity. I experimented with additional patterning in CLO 3D software and decided to set aside the project for my BFA capstone. Figure 36 depicts my experimentation with silicone grip patterns on the knit fabric.

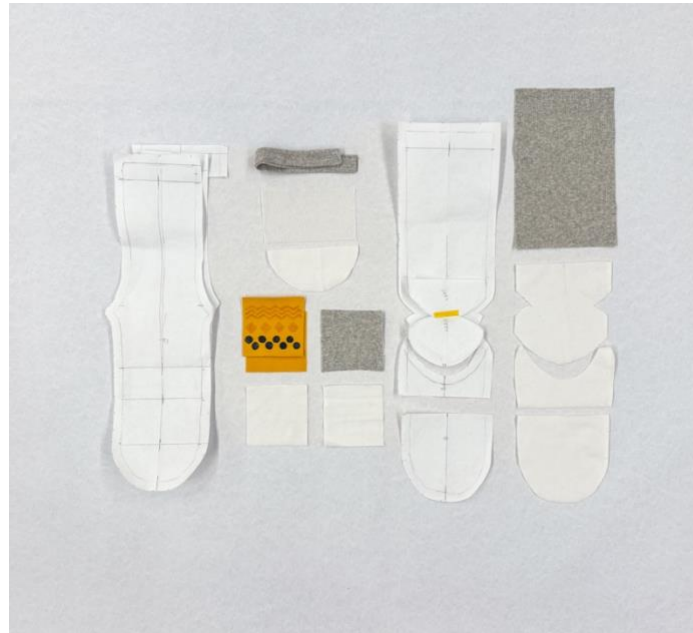


Figure 35: Paper patterns for a full-length sock

Paper patterning a zonal material mapping for the grip sock resulted in a sock that was too tight to fit the women's size 8 soccer last.

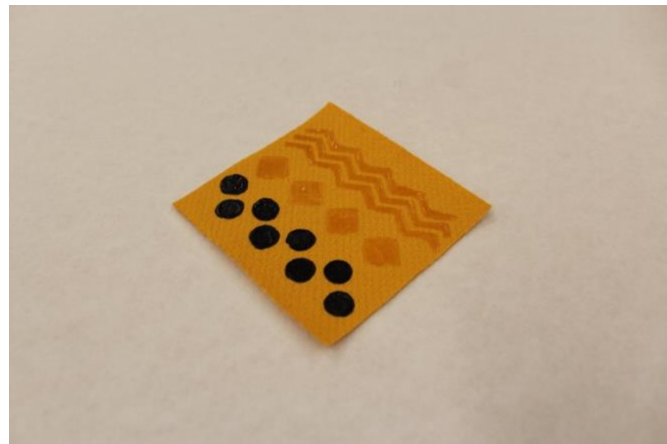


Figure 36: Silicone patterns on polyester knit fabric swatch

All three silicone circle, diamond, and chevron patterns provided frictional resistance that limited the swatch from sliding compared to a smooth swatch without silicone.

In addition to experimenting with socks and silicone grip patterns, I created two “works-like” insole prototypes for user testing. In Figure 38, the insole on the left with the white

polyester knit top cover represents insole #1, a dual-density insole with grip. It has three black and six translucent silicone 3 mm-diameter circles on the medial post for grip and is made of a 4 mm black open cell foam that is molded around the last with cupping around the heel. It includes a PLA stability plate with a medial post made of both PLA and 2 mm grey closed cell foam, and a hole in the heel of the plate for a less dense 4 mm blue open cell foam circle to provide extra cushioning in this high plantar pressure zone. The blue insole represents insole #2. It has a blue polyester-elastic cover atop a 3 mm thick grey open cell foam that fits a PLA stability plate that projects slightly further forward than insole #2. Figure 38 shows the bottom view of both insoles.

The surface transitions in the two insole prototypes are based on the specific shape of the women's size 8 soccer last and anatomical landmarks pictured in Figure 39. It was especially important to terminate the PLA stability plate before the metatarsal phalangeal joint as to not interfere with the plantar plates, plantar fascia and ligaments in the foot's windlass mechanism. The windlass mechanism occurs as the toes extend in dorsiflexion, plantar fascia wrap around the metatarsal heads, and the arch becomes taught to transition the foot from a flexible structure to rigid level to support weight and propel the body forward.

The key functional benefit of the insole prototypes is the integration of medial posting in the full-length insole to correct overpronation, accommodate for the generally shorter instep by filling more space in the shoe, and improve foot alignment. The medial posting on insole #1 is about 5 degrees and insole #2 is about 2 degrees. The common range of correction is 2-8 degrees.



Figure 37: Top view of insole #1 (white top cover on the left) and insole #2 (blue top cover adjacent)

Top view of two mid-fidelity insole prototypes, foam swatches, and 3D printed test disks with varying levels of gyroid infill (10% vs 15%) and pattern (gyroid, grid, honey, and trihexagonal).



Figure 38: Bottom view of insole #1 (black and blue foam and white PLA sulcus) and insole #2 (grey foam and white PLA stabilizer plate)

Bottom view layers showing that insole #1 has a more prominent medial post than insole #2.

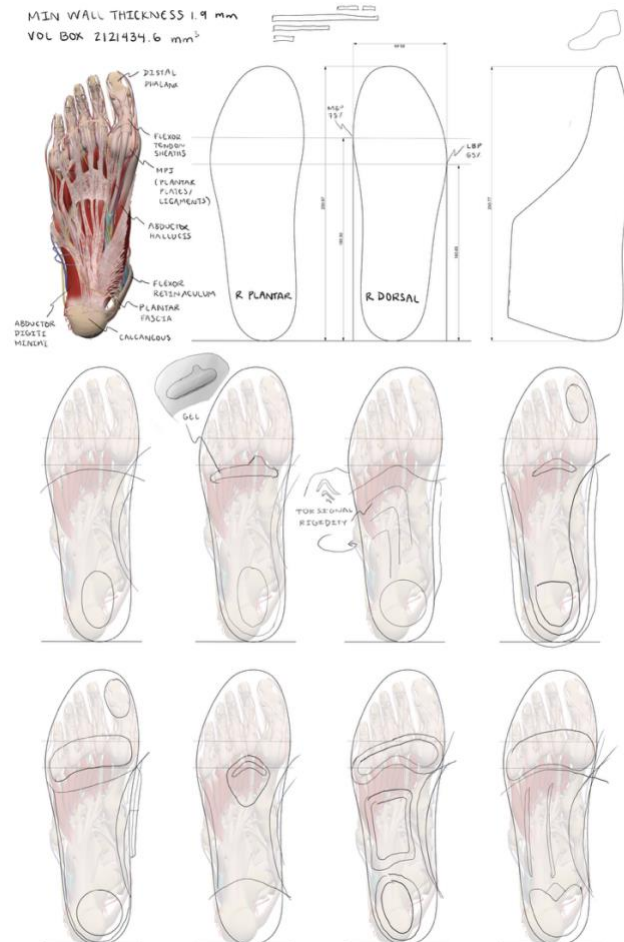


Figure 39: Anatomical mapping for insole surface transitions

In designing the stability plate surface transitions, it was important not to obstruct the function of the metatarsal phalangeal joint head.

## Concept Validation Testing

### Overview

The biomechanical studies reviewed in Section I and conducted at the BSSC in Section II lacked qualitative data on athlete perception. The way that an athlete feels and thinks impacts how they play, but this cannot easily be shown in objective or quantitative measures. For example, comfort is a subjective term. Shoe comfort is influenced by insole plantar pressures, shoe size,

shape, style, mass flexibility, climate, cushioning, materials, and tread. When conducting concept validation testing, I kept conversation open ended with the athlete while she performed a fixed set of tasks to allow her the opportunity to share unfiltered feedback on the comfort levels of the prototypes. When compared to laboratory testing, this concept validation testing is quite rudimentary given the limited material constraints. Nonetheless, the objective of this validation testing was to understand whether a custom insole concept could be one part of the solution to empower female soccer athlete performance by building trust in supportive gear.

### *Methods*

Athlete SG, whom I previously conducted an interview with, provided informed consent to test the insoles in low-risk tasks at their home turf field at Pacific University. SG wore a brand-new pair of the IDA Rise turf shoe in size 8 that were purchased for with SCORE-Knight Campus research funding for this study. I used a 1” square of blue tape to mark her hip on the anterior superior iliac spine (ASIS), knee at the midpoint of the femoral condyles, and ankle at the midpoint of the malleoli to be later used for measuring the frontal plane projection angle (FPPA) and knee flexion. I set up a tripod to record her frontal plane movements for analysis later.

After a self-guided 5-minute warm up of dynamic stretching and light jogging in the IDA Rise turf shoe. SG was instructed to perform six trials of five drop jumps, five single leg hops on the right leg, five lunges with the right leg forward, and 5 cuts in both directions with rests in between each activity and each trial. In trial 1 and 4, SG wore the control factory insert that accompanied the IDA Rise. In trial 2 and 5, SG wore insole #2 (blue insole prototype). In trial 3 and 6, SG wore insole #3, (white insole prototype with grip and medial post). Six trials were

written in the methodology to allow for the athlete to familiarize themselves with the instructions of the protocol.

### *Results*

I gathered verbal feedback throughout the process to initially validate the insole prototypes. First, SG noted that the control insole felt flat, stiff, and brand new. She said “I can feel everything beneath my feet with this insole. And I notice a huge space under my arch.” When asked to kick the ball against the wall while wearing the control insole, SG noted “Since there’s so much space, I feel the middle part of the shoe squishing in.”

When wearing insole #1, she felt the fit to be a lot tighter than the other insoles and mentioned that she might need a bigger shoe for it. SG said that insole #3 had the most heel cushioning out of the three models, but that eventually, it felt like her heel might pop out of the shoe. SG described “It’s obviously not going to come out of the shoe, but it’s just so high up that it has that feeling that it would.” She also mentioned, “This insole feels a lot more comfortable, but it squishes the top of my foot up against the shoe.” Additionally, she noted that she would be concerned if constant pressure on the medial part of the shoe from the medial posting of the insole and ball contact would wear down the shoe. On this note, she said, “[The contact] is not uncomfortable for me, but maybe for the shoe’s wear over time.”

When performing the tasks with insole #2, SG said that she could sense a bit of arch support, but she felt her foot sliding—especially during the lunge. She liked the placement of the medial posting support and did not feel like it dug into her foot nor the cleat. SG said stated “I feel a difference in cushioning with this compared to the very first one.”

## *Discussion*

Considering SG's feedback, further modifications must be made to reduce the material thickness of the insole prototype to better fit the shoe. I previously outlined the original success criteria for the solution to have a) compatible fit with the athlete's existing gear; b) arch support to minimize the risk of overpronation; c) durable comfort for extended wear; and d) balance the need for slip resistance within the shoe and dynamic movement beyond it. Based on SG's wear testing feedback, the insole prototypes need modification in all four areas. Specifically, the dual-density material composition of insole #1 is most promising for providing durable comfort for extended wear, but the thickness of its PLA stability plate and black open cell foam must be reduced to a total of 4 mm to be compatible with the constrained space within the IDA Rise shoe. For in-shoe traction, the white polyester knit on insole #1 with added silicone circular grip nodes was more favorable than the slippery blue polyester-elastic knit on insole #2. Both insoles provided proprioceptive feedback for the athlete to be more aware of the position of the ankle and foot, which validates that that medial posting on the PLA stabilizer plate with added foam cushioning may help promote more favorable joint stability.

Moving forward, I'd like to evaluate whether the medial posting helped promote ankle stability for SG using the joint kinematics. I was only able to record SG's drop jumps, single leg hops, lunges, and cuts in the frontal plane, so I could only calculate the frontal plane projection angle (FPPA) of the knee. While I am currently analyzing the videos, I have yet to find significant differences between the three prototypes, which suggests that SG's ankle alignment might not be influenced by the arch support on an objective biomechanical scale, but only on a subjective scale. Although I waited until the end of the session to tell the athlete SG about the

differences between the prototypes, she was not blind to the purpose of the study, which may have introduced bias. In other words, the modified insoles might have a placebo effect, if not somatosensory feedback for foot muscle engagement or slight performance benefit in a mental boost of confidence. The limitation of this type of analysis is that FPPA is a measurement of the dynamic Q angle based only on the frontal plane (hip adduction, knee abduction), and excludes the transverse plane (hip internal rotation, tibia external rotation) and patella behavior. An extension of this project must include more prototypes varying in material, grip patterns, and grip placement; more eligible athletes for testing; and a written questionnaire for the athlete to provide feedback on the prototypes with anonymity and privacy immediately following each trial to reduce the risk of the researcher's presence influencing the athlete's perception. Upon gathering additional athlete biomechanical and perception data, I can then create a more well-informed final concept.

The final concept will follow this thesis publication as it is a part of my BFA in Product Design capstone project. My honors college thesis defense slide deck and BFA capstone project can be found on my portfolio website [www.audreysaing.com](http://www.audreysaing.com) starting June 9<sup>th</sup>, 2025.

## **Conclusion**

### **Next Steps**

Ultimately, this project was an exploration of biomechanical and design insights relating to women's soccer. The next steps of this project are to refine the design of prototypes and further tests them in different sizes and material composition with more female athletes. While the data collection in section II of this thesis was well-equipped with pressure-sensing insoles, force plates, 3D motion capture systems, and a biomechanics lab, the data collection in section III was much more rudimentary. The concept validation in section III requires more expert support to investigate the videos for joint kinematics and frontal plane projection angles. Ideally, I would partner with an existing lab to conduct further validation testing on future iterations of the insole or other solution to the female-centric gear problem.

### *Reflection*

Throughout this research and design process, I found myself struggling to keep the athlete's holistic needs at the core of my pursuit of a concise evidence-based solution to a single problem. Despite the guiding north star, I became disheartened learning about the excess production and unsustainable consumption of products that are not backed by research (Figure X). Much of the materials and product manufacturing for sports apparel and footwear occurs in Southeast Asia. In another life, instead of a Cambodian American immigrant, I might be the Cambodian garment factory worker. As an emerging researcher and designer, I am wary of joining an industry that normalizes the exploitation of labor for rapid production cycles. A future extension of this thesis project requires deeper partnership with athletes and existing

professional, recreational, and social women's sports organizations to justify the insole concept (or a different solution) for further development.

At the end of this honors college journey and five years of undergraduate education, I realize that my immediate next step must be to recharge my energy through weaving, berry picking, and resting amidst the trees and river water. Although I often feel guilty for taking breaks when I could be doing work instead, one of the biggest life lesson's that I have learned in the past five years is that I cannot pour from an empty cup. After some time spent recharging, hopefully I can get more involved in women's sports and community organizing for social justice while working in the service, industrial, or soft goods design industry. Thank you for being part of this journey.

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