Ettōr: Sand Running Footwear Inspired by the Marshall Islands

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Introduction

Fossil evidence has shown that endurance running capabilities in humans originated around 2 million years ago. The ability and evolution for humans to run long distances enabled them to evade predators and also hunt for food (Bramble, Lieberman, 2004). The long-distance running capability eventually evolved from primarily hunting and surviving, to competitive sport in 776 B.C. in Olympia, Greece. This event, the ancient Olympics, was the first recorded event that included competitive running. Competitors came from many different Greek cities and competed against one-another in foot races (*The Olympic Games: Locations, Facts, Ancient & Modern*, 2010). In 1896, the first modern Olympic Games took place in Athens, Greece, including running events such as the marathon. This event modernized competitive running and was the start of foot racing as we know it (IOC, 2018).

Figure 1
(*Micronesian Games - Alchetron*, 2017).

Competitive running first reached Micronesia, a region of the western Pacific Ocean, in 1969 during the Micronesian Games. The first Micronesian Games took place in the Northern Mariana Islands and included track and field events (*Nauru will host Micronesian Games*, 2022).

Countries that competed in the 1969 Micronesian Games included the Northern Mariana Islands, Palau, Truk, Ponape, Yap, and the Republic of the Marshall Islands (*Micronesian Games – Alchetron,* 2017). The Republic of the Marshall Islands, the Marshall Islands, or the RMI, is a country located halfway between Australia and Hawaii, in the western Pacific Ocean. The RMI has 29 atolls and 5 low coral islands, which amass to 70 square miles of land, containing mostly sand and coral terrain (Kiste, n.d.). In the RMI, there is a lack of sports facilities and access to exercise equipment. Proof of the lack of facilities is shown in their sports participation internationally. For example, the RMI is the only country in the world that doesn't have a FIFA recognized soccer team. The primary reason for this is because a requirement to be a part of FIFA is to have a soccer facility. This can be attributed to the lack of funding for sports teams and sports facilities (Rogers, n.d.). Unemployment is high (40%) in the RMI, and 30% of the population of the main two cities, where 75% of the population live, are living below the basic-needs poverty line (Blair, 2016). Charles Paul, the ambassador to the U.S. from the Marshall Islands, has said that the nation can't survive without aid from other countries, such as the United States (Blair, 2015). Funding for sports and sports facilities isn't a main priority for the Marshall Islands.

The lack of access to sports and exercise facilities can be attributed to the rate of overweight and obesity in the RMI, which is a little over 70% of the adult population (18+), according to data from 2017-2018 (Wu, Cowan, 2017). On top of the limited access to sports and exercise facilities, the islands are up against the effects of climate change. By the year 2035, the U.S. Geological Survey projects that some of the RMI will be underwater, and many citizens will have to leave the country due to the effects of climate change and rising oceans (Bordner, Ferguson, 2020).

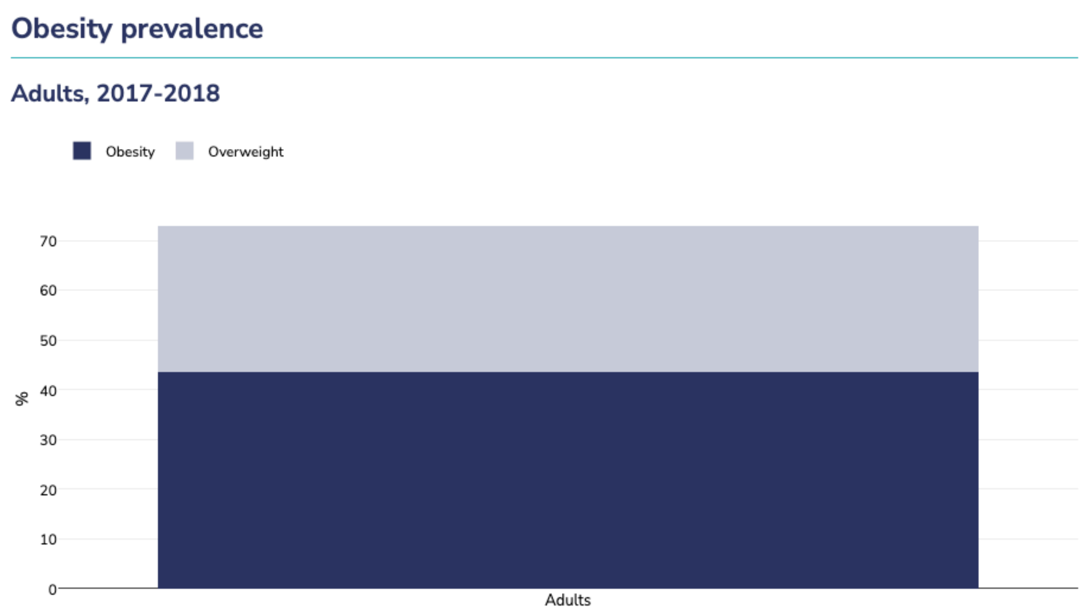

Figure 2
(*Marshall Islands,* n.d.)

The RMI struggles to find the resources to fund sports and sports facilities, battle obesity, and climate change. The country is progressing to find solutions to these problems though, including the opening of a new track and field stadium in the capital city, Majuro. The stadium will also act as a sea-wall to combat the rising sea levels. This new facility will provide the access to sport that the country is lacking, and combat not only the rising sea levels, but potentially obesity and participation in sport as well (*Future Marshall Islands Stadium,* 2022). This capstone research will be looking at creating innovative, performance running footwear, conscious of the challenges the Marshallese people are facing today.

User

There are around 60,000 people that live in the RMI (*Republic of the Marshall Islands country brief*, n.d.). Of these 60,000 people, around 15,000 people are in the 13 to 25-year-old age group, and there is around a 50% split of males and females. That makes around 7500 of the 60,000 Marshallese people male, and aged 13-25 years (*Digital 2022: The Marshall Islands*, 2022). This age group will be defined as male youth and young adult. This group was chosen to reflect the new track and field stadium opening in 2023, where this age group will be able to be the first generation of Marshallese people to utilize and train at a high level. The target user has any level of experience in long-distance running within the 13 to 25-year-old age group.

At the 1972 Summer Olympics in Munich, Germany, Frank Shorter was the winner of the men's marathon. Shorter was the first American to win the event since the 1908 Summer Olympics and became the primary catalyst to the "long-distance running boom" of the 1970's in the United States. Research into the running boom has found that the marathon win in 1972 influenced the "development of a broader fitness culture that stressed personal responsibility for health." It was reported that during the 1970's in the United States there was an increase from around 3 million runners to almost 30 million runners at the end of the decade (Haberman, 2017). Today, the United States is amidst another running boom, thought to be caused by the COVID-19 pandemic and the motivation to change physical health. It is reported that 28.76% of runners in the United States right now started during the pandemic (Rizzo, 2021).

The Marshall Islands is a country that is facing many challenges, and one of them is physical health. With 70% of the adult population in the overweight or obese demographic (Wu & Cowan, 2017), the Marshall Islands needs a catalyst to influence a change in the rate of overweight and obesity. The opening of the track and field stadium in 2023 in Majuro, Marshall Islands can be the catalyst event, just as Frank Shorter's marathon win in 1972 and the COVID-19 pandemic influenced the United States to change physical health of the American people. The male, 13 to 25-year-old, and with any running experience Marshallese demographic will have the opportunity to be the first generation to train, race, and win in a track and field stadium, just as Frank Shorter did, and potentially influence a change in how the Marshallese people view physical health. This running footwear capstone will look to be a part of the influence of reversing the current state of physical health in the Marshall Islands.

Environment

The Marshall Islands has a warm, tropical climate year-round, with an average temperature of 80 degrees and high humidity (*Marshall Islands - Climate*, n.d.). Most of the terrain in the Marshall Islands is sand and coral, although Majuro, the capital of the RMI, has a 32-mile continuous road (*Marshall Islands geography*, n.d.).

Based on the terrain of the Marshall Islands, a long-distance runner would have to mostly run on the sand to train for running events. Typically, in long-distance running training, 70% of the overall running training volume is completed at a low-intensity heart rate, and the other 30% is completed at threshold or high-intensity heart rate to influence physiological adaptations for racing (Campos et. al, 2022). This capstone project will look to find a solution to optimize for sand running, with a solution to training at a low-intensity and threshold or high-intensity heart rate zones. There are currently no options in the running footwear market that is optimized for efficient sand running. The high average temperatures and humidity also will be taken into consideration when designing and creating footwear for this environment.

Figure 3
(*Marshall Islands travel guide,* n.d.)

How Can We

Create running footwear for people looking to train the Marshall Islands, or other sandy beach environments, that is optimized for performance and injury prevention?

Jobs To Be Done

A long-distance runner today in the Marshall Islands would not have running footwear that would enable them to train optimally in high heat and humidity, and on sand. The footwear created for this project will need to function similarly to other running footwear in terms of what jobs an upper, midsole, and outsole serve for the athlete. The main difference and the innovation of this project is optimizing for the Marshallese environment, specifically solving for outsole traction on sand, and an upper that is optimized for the hot and humid climate.

A Marshallese long-distance runner will need a running footwear option with an upper that can allow the athlete to properly thermoregulate. In a study that looked at the thermo-physiological response when wearing half-length boots and sandals, it was found that "how feet are covered by different types of shoes could influence the thermoregulatory response of the whole body." When wearing the sandal, it was found that users had a lower core temperature and heart rate than the half-length boots (Kawabata & Tokura, 1993). Using this research and given the hot and humid climate of the Marshall Islands, an upper for running footwear in the Marshall Islands can be the upper of a sandal rather than the typical running shoe that covers the entire foot. This idea of using a sandal upper can help solve for thermoregulation problems when in the heat and humidity.

The other main job to be done for a Marshallese long-distance runner is solving for traction on the sand. There are currently no running footwear options for training on the sand, and the Marshall Islands' terrain is comprised of mostly sand. The outsole traction for this project should focus on optimizing the experience of running on sand and attempt to reduce the risk of injury and lower the metabolic cost on sand at a low-intensity heart rate when compared to other competitor options.

Product Rules

This project will look to adhere to the ASTM, the American Society for Testing and Materials, standards for athletic footwear. The upper of running footwear is defined as "the entirety of the shoe that sits on the rubber sole" (Anatomy of a Running Shoe, n.d.). The upper of the created footwear will look to adhere to the ASTM F539 standard, which tests the fit of footwear. Improper footwear fit is defined as "either too loose or too tight on the foot for its intended purpose or protection thereof" (Standard Practice for Fitting Athletic Footwear). This method consists of the user wearing the created footwear and transferring their weight forward. If the material wrinkles and folds, which indicates weight on the upper rather than the sole, then the footwear is considered to have an improper fit (Standard Practice for Fitting Athletic Footwear, 2022).

The ASTM defines athletic footwear cushioning systems as "all of the layers of material between the wearer's foot and the ground surface that are normally considered a part of the shoe. This may include any of the following components: outsole or other abrasion resistant layer, a midsole or other compliant cushioning layer, an insole, insole board, or other material layer overlying the midsole, parts of the upper and heel counter reinforcement [...] and other cushioning layer inside the shoe" (Impact Attenuation of Athletic Shoe Cushioning Systems and Materials, n.d.). The testing for this project will reference the ASTM testing standards for footwear cushioning systems. Cushioning of the midsole will adhere to the ASTM 1976-13 standard, which is the testing method for impact attenuation of athletic shoe cushioning systems and materials. This method will determine if the created footwear will decrease the loading impact of ground reaction forces and reduce the risk of injury (Impact Attenuation of Athletic Shoe Cushioning Systems and Materials, n.d.). The method consists of "using an 8.5 kg mass dropped from a height of 30-70mm to generate force-time profiles that are comparable to those observed during heel and forefoot impacts during walking, [and running] landings" (Impact Attenuation of Athletic Shoe Cushioning Systems and Materials, n.d.).

Outsole traction, which is defined as "resistance to relative motion between a shoe outsole and a sports surface," typically uses the standard method of linear traction testing. This method, ASTM F2333, consists of using a strain gauge to measure the amount of rectilinear motion parallel to the athletic ground surface of the footwear being tested (Traction Characteristics of the Athletic Shoe-Sports Surface Interface, 2022).

The general rules of running training are to stay safe, and to stay injury-free. In terms of safety, it is important to start with wearing footwear that fits well, and has a proper, shock-absorbing sole to reduce the risk of injury. Aside from the footwear worn, it is important to train within the limits of your body, and to not run with pain. When running outdoors, it is wise to run in areas that are known to be safe, whether that is from hazardous objects, or if it is safe from people and animals (Anzilotti, 2019). In terms of staying injury-free from chronic injuries, one should train within the limits of their body. It is recommended that when training, 70% of the total running volume should be at a low-intensity. This is a good guideline when training to increase fitness, but also a good guideline to stay within the limits of the body. If the amount of total training at a higher intensity is increased, then the risk of injury increases as well (Campos et. al, 2022). Runners in the Marshall Islands should look to follow the running rules of safety and staying injury-free and stay out of hazardous areas and train within the limits of the body.

Market

The Marshall Islands is home to 60,000 people, with a large percentage of the Marshallese population in the 13 to 25-year-old age group. 25,000 Marshallese males are under the age of 25 (Republic of the Marshall Islands country brief, n.d.). The number of current runners in the Marshall Islands is unreported, although there were 2 participants at the 2016 Summer Olympics in track and field (Littlefield, 2016). Outside of the market specific to male Marshallese runners aged 13 to 25, the global running footwear market is expected to increase greatly through the year 2028 (Global Running Footwear Market, n.d.).

The current running footwear market in the Marshall Islands is unreported, although in 2013 it was reported that the total cost of all imported footwear into the Marshall Islands was $1770 (Product Exports by World to Marshall Islands, 2013). The priority of footwear currently in the Marshall Islands is not large, according to this low amount of imported footwear from 2013. The population of the Marshall Islands in 2013 was reported to be 56,933 (Demographics, n.d.). With these statistics in mind, as well as the amount of people living below the basic-needs poverty line, it can be assumed that the priority for purchasing footwear was and is very low.

Product Anatomy

The anatomy of functional running footwear consists of an upper, a midsole, and an outsole. The upper is everything that is above the sole of the shoe (Footwear ñ Running Shoe Anatomy, n.d.). The upper is the fabric part of the shoe that secures it to the foot. Within the scope of running in the Marshall Islands, the upper of running footwear should keep the feet protected

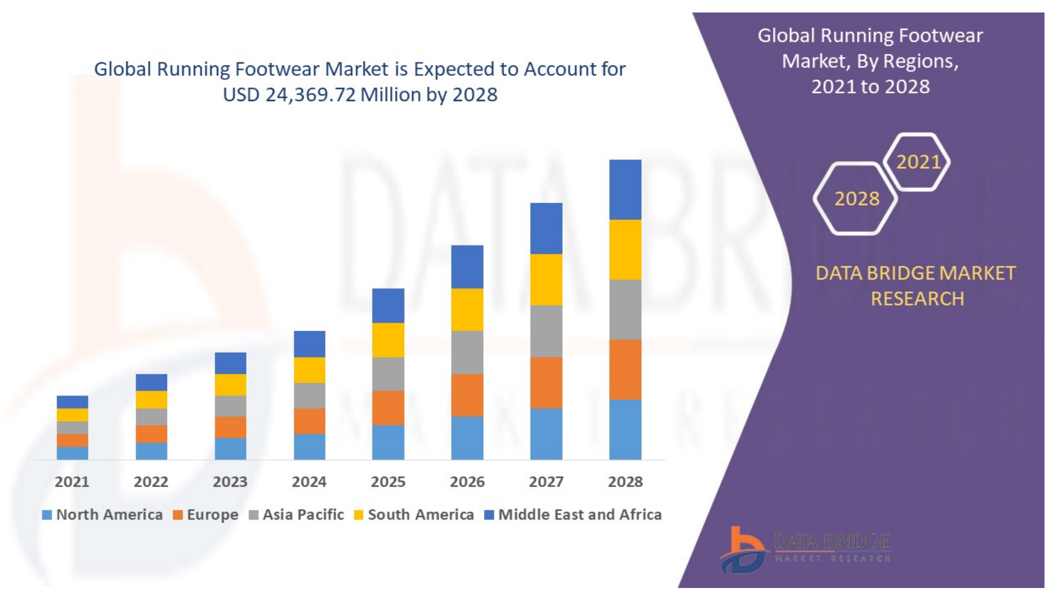

Figure 4
(*Global Running Footwear Market*, n.d.)

from the elements, lock-down the foot, and provide stabilizing elements if necessary. Stability features or elements include heel counters, external straps, and other elements that aid in stabilizing the foot during athletic movement (Footwear ñ Running Shoe Anatomy, n.d.). In terms of this project, which is looking to create a running sandal, the upper anatomy for this project will be sandal straps that lock-down the foot to reduce movement of the foot while running.

The midsole of functioning running footwear is between the upper and the outsole and is typically made of foam. The midsole provides the most important aspects of cushioning and stability for running footwear (Footwear ñ Running Shoe Anatomy, n.d.). In the scope of this project, the footbed will differ from traditional running shoes where an insole provides cushioning and shock-absorption but sits on top of the midsole. This project will look to incorporate the elements of cushioning and shock-absorption into the top of the midsole rather than being a separate entity, as shown in the figure below. The midsole of the created shoe should provide cushion and stability needed when running on the sand. Stability elements should protect the user from dangerous movement patterns that may occur when running.

The outsole is the final main component to functional running footwear anatomy. The outsole is the bottom of the footwear and is typically made of rubber. The outsole provides traction elements that provide grip and are specified for the training environment (Footwear ñ Running Shoe Anatomy, n.d.). In the environment of the Marshall Islands, the outsole should provide traction in the sand to provide grip and protection from movement patterns that can negatively affect the user when running.

The figure below looks at the anatomy of the Chaco Lowdown 2 Sandal, a performance athletic sandal. The anatomy of a performance athletic sandal is simple, with the main innovation being the orientation of the sandal straps and how the straps can secure the foot during athletic activities. In the created footwear for this project, the Chaco Lowdown 2 Sandal will serve as inspiration for how the foot can be secured with different strap orientations, although the straps will be oriented and innovated upon to lock-down the foot when running on sand.

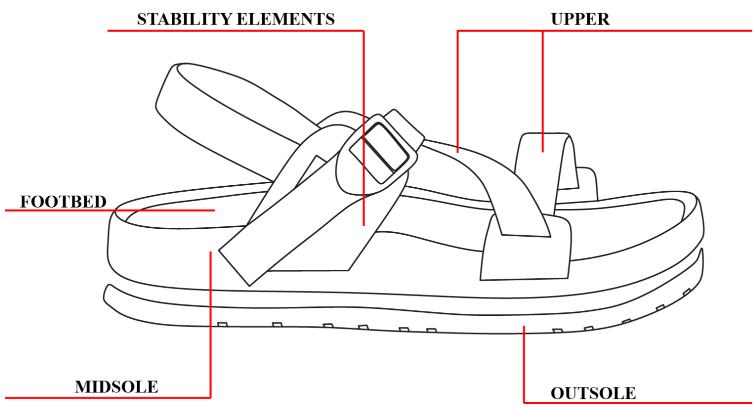

Figure 5

Anatomy of a Performance Athletic Sandal (Rehm, 2022)

Materials

Materials in typical function running footwear will generally include a durable fabric for the upper, foam for the midsole, and foam or rubber for the outsole. The upper should secure the footwear to the foot, the midsole should provide cushion and stability, and the outsole should provide traction. With these guidelines in mind, this capstone project will look to create running footwear that function as well or better than existing running footwear options. The upper should provide stability for the ankle, as well as ample cushioning and protection at the heel and dorsal aspect of the foot. The midsole should provide cushion and stability, and the outsole should provide traction for the user.

This capstone project will look to optimize performance and injury prevention for the user, but in the form of a running sandal. This will pose difficulties, as a full upper of a traditional running shoe can provide many aspects of foot lockdown, cushioning, and more. On the other hand, a running sandal silhouette can offer different positive aspects that a traditional running shoe cannot, such as more airflow and cooling for hot environments, as well as lighter weight in the upper. The midsole and outsole can essentially provide the same benefits between both types of silhouettes. This project will look use the highest performing materials possible to solve for the difficulty of sand running, that has yet to be accomplished. Current materials of performance athletic sandals will typically include nylon or polyester webbing for the straps. Some top-of-the-line performance sandals will include a liner of a softer material, such as neoprene or spandex, for comfort to the skin, such as the Hoka Hopara or Merrell Speed Fusion sandals (Nelson, 2023). Since this project will look to optimize for the highest performance aspects for sand running, utilizing higher end materials that provide comfort to skin, such as neoprene or spandex, that the higher end performance sandals currently utilize.

Top of the line performance running shoes will offer a carbon fiber plate or a similar composite, that offers stiffness and response to propel the runner forwards and offer a higher energy return. These running shoes will usually have the carbon fiber plate, or the like, molded into the midsole, which this project will look to replicate (Sayer, 2022). The benefits of these stiff plates are shown and researched in running shoes such as the Nike Vaporfly 4%. The main take-away from this shoe model is that the footwear improved running economy, or running faster when exerting the same effort, as compared to other running footwear offered in the market at the time of its creation (Sayer, 2023). When looking to fill the gap of performance running footwear optimized for sand running, this type of innovation will look to be recreated, in order to offer the highest performance possible in a difficult mode of running.

For the midsole materials, given the demands of sand running, this project will look to utilize the highest end materials to provide the best experience in a difficult activity. Current foams used in running midsoles include EVA, PEBA, PU, e-TPU, and more. Each foam offers its own benefits and restraints. PEBA, or polyether block amide, offers the lightest weight, best cushioning, and the most response, compared to the other foams. The only restraint of this foam is its durability, which is the lowest of all of the foams. On the other end of the spectrum, PU, or polyurethane, offers a lot of durability, but is the heaviest weight, and offers lower cushioning and response (The Types of Midsole Foams, n.d.). This capstone project will be designed with the goal of offering the highest performance possible in sand, which would look to have the highest response, light weight, and high cushioning, that a foam like PEBA would offer.

The outsole materials will look to replicate the highest performing running footwear as well. Rubber is typically the main material of choice, and its performance can be dictated from its manufacturing process, such as carbon rubber, which offers high durability, and makes up many of running shoes currently. Blown rubber, is lighter, softer, and more flexible than traditional rubber (Running Shoe Components, n.d.). This capstone project will look to optimize for high performance in an abrasive sand surface and utilizing the highest performing rubber material will provide the best benefit for the sand running experience.

Figure 6

Hoka Hopara (Ronto, 2023)

Manufacturing

Modern manufacturing of footwear starts with cutting the material in the shapes and forms needed for the upper and sole. Next the upper and sole and attached, in a process called "lasting." During lasting, the upper is pulled over the last, and will take shape of the last. Then, the bottom heel in its final molded form is connected to the rest of the footwear, in a process known as "heeling" (Cole, 2021). The upper for this project will aim to be for a sandal, to optimize the running experience in the hot and humid climate of the Marshall Islands. A traditional upper for footwear will be die-cut by steel dies in a hydraulic press (Motawi, 2016). Simple sandal uppers can be created through simple paper patterns and draping (Turner, 2021).

Typical manufacturing of a midsole and outsole will include injection-molding or printing around encapsulated technology. After the midsole and outsole are created, the upper and the midsole will be attached or cemented, and then the outsole cemented to the midsole, as traditional footwear is manufactured (Motawi, 2018).

Figure 7
(Turner, 2021)

Line Plan

The initial line plan of this project will be 2 performance running sandals of different upper construction, but still offering the proper cushioning and foot lockdown. One of the sandals will look into optimization for running in the sand, offering high performance and high-intensity running in this environment. The other sandal will look to optimize for recovery or lower-intensity heart rate running, offering cushion and comfortability.

Colors

According to WGSN's color forecast for activewear in Spring and Summer 2024, "key [color] directions for S/S 24 activewear [include] tones that play into the continuing importance of emotional support, product longevity and bringing digital and physical worlds" (Kostiak, 2022). Some of these key colors are very similar to the blue, orange, and white colors of the Marshallese flag. Hues of blue such as tidal teal, galactic cobalt, cornflower, and elemental blue can represent the blue of the Marshallese flag. Sweet mandarin and apricot crush can represent the orange of the Marshallese flag, and pumice and optic wave representing the white.

Running footwear for the Marshall Islands should include colors of the country's flag because it is the first footwear that is made specific to the culture of the country.

Figure 8

Flag of the Marshall Islands (Smith, n.d.)

Visuals

Current activewear visuals or graphics, per WGSN, include eco-conscious highlights. As more people are becoming conscious of our earth and climate change, more companies have displayed graphics that show they are creating products that are eco-conscious. Advertising eco-conscious branding is a current trend in activewear companies and align with the commitment activewear brands have to moving to recycled materials and eco-conscious manufacturing to combat climate change (Kostiak & Jamali, 2022). WGSN provides two examples of what visuals or graphics should be included in the future. According to the WGSN Active Forecast for S/S 24, maximum resourcefulness will be a graphic trend. Maximum resourcefulness includes using materials that you already own, and visual elements that can be changed or replaced (Kostiak, 2022) Activewear companies are utilizing this trend by not trying to hide that the materials used are pre-owned or recycled through visual elements such as elements of distress in the material. Utilizing recycled or re-used materials should be a goal for this project, and all footwear moving forward, in order to reduce the effect, the footwear industry has on global warming and climate change.

Another visual trend that WGSN provides as insight into future trends in 2024 is Deconstruct and Reconstruct. In WGSN's Sneaker Materials Forecast S/S 24 article, "growing demand for designs that can either be easily repaired or recycled easily will see a rising focus on more considered materials and modularity" (Kostiak, 2022). This trend goes along with the Maximum resourcefulness trend, because the concept is based on incorporating up-cycled or environmentally conscious material elements. Being able to take apart and put together the footwear to repair rather than purchase new footwear is the basis of this trend. In the 2024 sneaker materials forecast from WGSN, it is predicted that "uncertainty will continue to be a dominant force in 2024 due to ongoing [environmental crises]" (Kostiak, 2022). This is pertinent to the environmental crises that is occurring in the Marshall Islands today and will continue to be a concern in the future. The deconstruct and reconstruct trend will be especially relatable to the Marshallese people.

Branding

Statement simplicity is a main visual branding trend for Active Forecast S/S 24 by WGSN (Kostiak, 2022). This includes virtually no branding that is visible, which gives focus on the purpose and function of the footwear, and opportunity for circularity. Current running footwear options will include branding usually, which doesn't allow for inclusivity for all needs, and is uplifting and positive (Kostiak, 2022). This is a branding trend that can be important for Marshallese people, because the main purpose of the footwear is to function and be created for running in the Marshall Islands. Little to no visual branding will give focus to this function and be inclusive for all people of the Marshall Islands.

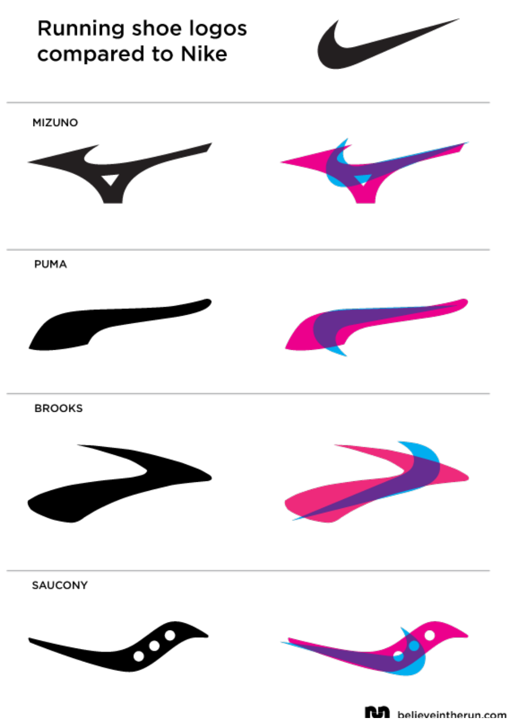

Figure 9
(Kostiak, 2022)

State-of-the-art branding in the current running footwear landscape are similar and look to mimic each other in simplicity and style. The Nike, Puma, Brooks, and Saucony branding are all very similar to each other, with the base shape being close to a check mark. The way that many running footwear companies do branding, is by placing their logo simply on the side of the shoe, usually on both the medial and lateral aspects. This is simple, and the side-to-side shape of the check can be more utilized in this fashion. The footwear for this project will have "statement simplicity," or no branding such as the main competitors in the market. The visual focus will be to the function of the footwear created, rather than to the logo of the brand.

Intellectual Property

Patents that pertain to the scope of this project for sandal strap orientation, stabilizing elements for footwear, outsole traction for sand, and shoe cooling. Additional information on these patents can be found in Appendix A.

Sandal Strap Orientation:

- Shoe, ankle orthosis and method for protecting the ankle (US6270468B1)
- Sandal strap arrangement and tensioning system (US9635899B2)
- Sport Sandal with Y-Strap (US20220007779A1)

Stabilizing Elements:

- Shoe, ankle orthosis and method for protecting the ankle (US6270468B1)
- Tendon assembly for an article of footwear (EP2670269B1)
- Article of footwear for sand sports (US7082703B2)

Outsole Traction:

- Article of Footwear for Sand Surfaces (US20220322783A1)
- Article of footwear for sand sports (US7082703B2)
- Footwear with sucker-type protrusions for sand protection (JP3152661U)
- Sole for article of footwear for granular surfaces (US7204044B2)
- Footwear with pontoon sole structure (US20140259784A1)

Shoe Cooling:

- Flow insole (US10010131B2)
- Footwear cooling system (US8191284B2)

Biomechanical Analysis

Running biomechanics can be generally defined through the running gait cycle. In the running gait cycle, there are seven phases, but these seven phases can be simplified into two main phases, the stance and swing phase. The first phase, and the start of the stance phase, is when the foot makes first contact with the ground. The stance phase ends when the same foot leaves the ground during "toe-off" and begins the start of the swing phase. The swing phase ends once the same foot contacts the ground again and enters the stance phase again (Wenxing, et.al., 2021). In-between these two phases of the gait cycle, there is a period of "float" where there is no contact from either foot and the ground. In this gait cycle, toe off "occurs before 50% of the gait cycle is completed" (Novacheck, 1998).

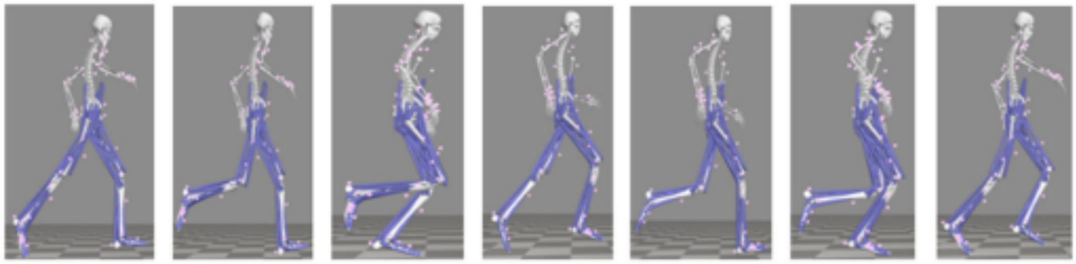

Figure 10
Running Gait Cycle (Wenxing, et. al., 2021)

Running biomechanics are imperative to staying injury free. In one study that assessed running gait and prevalent musculoskeletal injuries, it was found that "patients with [bone] injuries had significantly higher maximal [ground reaction forces]" (Lempke, et. al., 2022). Higher maximal ground reaction force can be related to the type of foot strike that an individual runner has. Between the three foot strike patterns, rearfoot, midfoot, and forefoot, it has been found that the forefoot strike pattern has "lower peak [ground reaction forces] than running with a rear foot strike pattern or mid footstrike pattern" (Jafarnezhadgero, et. al., 2021). Higher ground reaction forces can be related to a higher risk of injury and having a forefoot strike pattern can be the most likely way to reduce the risk of injury and ground reaction force. Ground reaction force and leg stiffness

Ground reaction forces (GRFs) have been found to differ on different surfaces during running. In comparison to normal over ground running, sand running has been found to have overall lower ground reaction forces than on a controlled, level ground surface (Jafarnezhadgero, et. al., 2019). In a study that measured both GRFs and electromyographic (EMG) activity, it was found that during the loading phase of running on sand, there was more EMG activity in the tibias anterior muscle, a lower leg muscle on the anterior aspect, as well as higher EMG activity in the vastus medals and rectus femoris muscles, two muscles in the quadriceps that are on the anterior aspect of the upper leg, compared to normal stable ground running (Jafarnezhadgero, et. al., 2021). Biomechanical differences between normal over ground surface and sand can be assumed to be different and employ higher activity and loading in the quadriceps when running on sand.

Pronation can be defined as the "combination of ankle dorsiflexion, rearfoot eversion, and forefoot abduction during the first half of stance phase." Severe overpronation, or over 15 degrees, has been seen to be a risk and a contributing factor to overuse running injuries (Ferber, Hreljac, Kendall, 2009). When designing this footwear project, comparison of sand to other surfaces should seek to find if overpronation should be a design consideration, in order to prevent the risk of injury when running.

Research on the difference between shod (running with a shoe) and barefoot running has shown that running shod has positive benefits for both reducing the risk of injury. Shod running has shown to have lower ground reaction forces than barefoot running, and therefore lowers the risk of overuse injuries in running (Thompson, Seegmiller, McGowan, 2016). Research on running gait biomechanics in flip-flops compared to barefoot and running shoes found that the time in the stance phase was greater in flip-flops than barefoot and running shoes, and also showed increased tibialis anterior activity (Zhang, Paquette, Zhang, 2013). This research shows that running in flip-flops will have more risk of injury than when running barefoot or in running shoes, since there is higher muscular activity during the stance phase, or when the body is taking on load-bearing stress. With this research in mind, providing a running footwear option for the ability to train in the Marshall Islands will also provide a means of reducing the risk of injury, and stray away from training barefoot or in flip-flops, as many Marshallese people wear.

Running Physiology and Psychology

Running performance is directly influenced by the environment. In high temperature and humidity running, the body will generally work harder at the same workloads than environments with lower temperature and humidity. Running in the heat will generally increase heart rate and redirect blood from the working muscles to the surface of the skin, which will allow heat to properly dissipate and allow the body to thermoregulate. This will therefore increase strain on the heart at the same workload when running at higher temperatures. With blood being redirected to the skin, the amount of oxygen being delivered through blood to the working muscles is lower, which also decreases the maximal work capacity (Cheuvront et al., 2003).

Sweat rates will also increase when running at higher temperatures in order to cool the body off and properly thermoregulate. This increase of sweat rate can lead to dehydration, and lower cardiac output. It has been found that there is a linear relationship between body weight loss and race finish times in marathon runners, and dehydration is found to be a cause of body weight loss due to losing water in the body through sweating (Goulet, 2012).

As mentioned, a study that looked at the thermo-physiological response when wearing half-length boots and sandals, found that "how feet are covered by different types of shoes could influence the thermoregulatory response of the whole body." When wearing the sandal, it was found that users had a lower core temperature and heart rate than the half-length boots (Kawabata & Tokura, 1993). In order to design footwear for high temperature and humidity, the physiology of running should be considered for design considerations. In order to allow the body to properly thermoregulate by not trapping heat, increasing the evaporation of sweat, and using materials that wick moisture and sweat, should be of high consideration. The use of lightweight, breathable materials will increase the air flow. Designing the footwear to be looser fitting, or more moisture wicking will also allow the body to properly thermoregulate, and therefore account for the physiology of running in the heat and high humidity.

Running in sand has been shown to have high metabolic strain compared to hard surfaces due to it being a consistent moving surface. One study found that running on sand requires 1.6 times more energy expenditure than hard surfaces. This is due to the increase of mechanical work in sand as well as a decrease in efficiency from the working muscles and tendons (Lejuene, Willems, Heglund, 1998).

Running in the heat can also have psycho-physiological strain. In one study by Nikol et al., they found that the perception of running in high heat will impair running performance through increasing the time-to-exhaustion. This psycho-physiological strain is related to the athlete having a higher perception of exertion (2018). Another study on running in the heat and the psycho-physiological strain found that the athletes running in the heat during the study, had "unpleasant feelings" and push into the forefront of consciousness, when there is heat accumulation without release (Allen-Collinson, Owton, 2014). During a study that measured rated perceived exertion (RPE) when using a cooling collar, an uncooled collar, and no-collar, found that those that had the cooling collar, a collar which was cold, had lower RPE, and "the performance benefits outweighed the reported discomfort" of the athletes that participated in the study (Antoinette et al., 2011).The effect of heat on psychology and its relation to physiology are very important and should be design considerations. If an athlete can feel cooler or have a lower RPE from wearing a certain material or design, then there should also be a positive psycho-physiological outcome. Performance has been directly related to the perception of heat for an athlete, and the Marshall Islands has high heat and humidity year-round.

Footwear Competitors

Specific research on footwear worn in the Marshall Islands is unreported but looking at images of people in the Marshall Islands tells the story of footwear. As mentioned, the islands are facing many challenges, one of them being income and funding towards sports and sports facilities. This occurs at the level of the government, and also the level of the individual people, where 30% of the main two islands live below the basic-needs poverty level (Blair, 2016). When searching for images of people in the Marshall Islands to understand what footwear choices there are currently, many images will show the Marshallese people either barefoot, or wearing a sandal. This may be attributed to culture, or the expenses needed for footwear, such as the $121 average in 2021 (Rizzo, 2021). Image searching showed the competitive landscape for footwear competitors in the Marshall Islands, bare feet, and a simple foam sandal.

Figure 11
(Grandinetti, n.d.)

Figure 12
(*Marshall Islands People*, 2021)

Bare feet and a simple foam sandal or flip-flop are the main two competitors in terms of footwear in the Marshall Islands. Without information or studies on what the Marshallese people run in also, it should be assumed that these two options are their footwear options if they were to train for long-distance running as well. When comparing the two options of "footwear," price is the first point to address. One is free, bare feet, and the foam sandal can be around only a few dollars due to the simplicity of the materials and manufacturing. When comparing the two in terms of features and benefits, the two footwear competitors are similar. One common theme in both of these are allowing for thermoregulation in the upper, due to the lack of fabric constraining the foot. The rest of the features and benefits can be found in the SWOT Analysis section.

SWOT Analysis

The current market for common footwear that is worn in the Marshall Islands can be broken down into strengths, weaknesses, opportunities, and threats in a SWOT analysis. The two most common options for what people in the Marshall Islands will typically utilize is bare feet and EVA foam flip-flops. The SWOT analyses below breaks down how these two options affect running, and also what can be taken away from the pros and cons of these two options when creating footwear for the Marshallese market. 2 other sandals were added that provide different performance aspects to provide insights into how a sandal can be optimized for running. When creating footwear for this market, it should address the strengths of these four options, and utilize these strengths in order to create footwear that allows the best performance for the market and target athlete.

	STRENGTHS	WEAKNESSES	OPPORTUNITY	THREATS
BAREFOOT 	No fabric, good upper thermoregulation Light weight	Shock absorption Protection from external elements Soft tissue damage	Utilize less fabric to provide thermoregulation, but also locking down the foot	Not specific to running
FLIP-FLOP 	Little fabric interaction, effective thermoregulation Toe post to grip and stabilize	Foot lockdown Multi-directional traction	Provide a sole for shock absorption and also a toe post for stabilizing the foot from slipping, with more foot lockdown	Not specific or optimized for running, could be uncomfortable over long distances
KEEN SHANTI 	Closed toe, preventing forward slipping Low profile Cushioned footbed Multi-directional traction	Heel support and lockdown Midsole cushioning Hard upper	Utilizing a cushioned footbed with a sandal, but with an open-toed concept and ample foot lockdown	More lifestyle than performance, not optimal over long distances
CHACO Z CLOUD 	Foot lockdown Multi-directional traction Protection from the ground	Heavy weight High profile, little proprioception with sand surface	Providing optimal foot lockdown but with a lower profile and lighter weight	Not optimized for running, too heavy for long distances

Figure 13

SWOT Analysis (Rehm, 2022)

Although these four footwear options are not typical of a running footwear landscape, these two best simulate the footwear market in the Marshall Islands. This project will look to take this into consideration, whether this landscape is due to income or culture, and find ways that the benefits of both of the two articles of "footwear" can be utilized in the created product.

Research Methods

Research methods for this project will be conducted in 3 different ways. One way is through internet research, which will aim to find design concerns for the Marshall Islands, and also find what current footwear Marshallese people wear. This will be conducted from November 1st through January 7th.

The next step for research methods will be using questionnaires to find more design concerns and also learn about trends of injury and knowledge of the terrain and environment. One questionnaire will be specific to the Marshallese people, and will aim to find interest in running shoes, current footwear worn, and knowledge of the target environment. The next questionnaire will be specific to athletes in beach and tropical environments, targeting collegiate runners. This will aim to find injury patterns, design concerns, and the amount of time spent running on the beach. The last questionnaire will be targeted towards athletic trainers and aim to find design concerns, injury patterns, and rehabilitation techniques employed. This will be conducted from November 1st through January 7th.

User Research Goals and Questions

Through research and questioning on the target user, information on how running on sand compared to other surfaces may impact performance and create design considerations. In the first set of research conducted to find this information, the questions will be directed to current runners that train on beach and sand terrain and climate. More specifically, the athletes that will be take part in the research are collegiate or post-collegiate runners that from colleges that are located on beach environments. The purpose of using this specific demographic is to find patterns of injury or concerns when training in this environment from athletes that have experience. Main questions that will be asked are “how much do you run in the sand or beach environment”, “are there any problems that you face when training in the beach environment”, and “what footwear would, or do you wear if you are training on sandy terrain?”

The next set of research will be conducted using the same colleges questioned but targeting athletic trainers. The purpose of this demographic is to find design considerations that can potentially come from knowledge of injury patterns that occur when training in this specific environment from the people that correct and prevent these patterns. Main questions for this group are, “do you experience problems or injuries from athletes training in the beach environment, and what are the problems or injuries” and “what type of rehab or preventions do you typically use for these problems or injuries?”

The final group that will take place in research questioning will be people currently in the Marshall Islands. This will be to find if there is interest, as well as if there are any experiences in running and training in the environment of concern, and if the target user can provide design considerations that pertain to training in the beach and sand environment. Main questions for the Marshallese people are “what footwear do you wear currently and what would you wear if you were to run on sand”, “what is your running experience” and finally, “what problems, if any, have you faced from running or training on the beach?”

Collegiate athletes in beach environments	
Question:	**Insight:**
What is your age, location, sex?	Does this person apply to my target user?
How often do you run on the sand or beach environment?	My user trains every day there, does this apply
Do you face problems when running in this environment?	Find consistent problems to fix
If so, what are the problems you face?	Find consistent problems to fix
What footwear do you currently run in?	
Does your footwear choice change when running in the sand or beach environment?	Is it different than their everyday running footwear choice? Is their common footwear people choose? What are the features/benefits that can be applied to my design
In terms of the upper, midsole and traction of running shoes today, what would the perfect running shoe build for sand running look like to you?	What would the ideal sand running shoe look like to an experienced runner?
In what ways does running on sand affect your running experience, positively and negatively?	How can I design to hit the pros and better the running experience in sand?

Time to complete survey: 3 minutes

Collegiate athletic trainers in beach environments	
Question:	**Insight:**
Have you experienced problems or injuries that have occurred from training at the beach or in the sand environment?	Are there consistent problems and injuries on this surface type?
What problems or injuries are there?	What is the modality of the injury? How can I solve for this in my design
What type of rehab/prevention do you use for these problems or injuries	How can my design accomplish how athletic trainers solve for the problems before and after the diagnosis

Time to complete survey: 5 minutes

Marshallese People	
Question:	**Insight:**
What is your age, location, sex?	Does this person apply to my target user?
Are you a long-distance runner? And if so, how often do you run long-distance? (Half a mile or more)	How many people is this project appealing to?
What footwear do you wear currently?	What are my true benchmarks?
Do you have footwear to run long-distance in?	Do Marshallese people have options for foot-wear to train long-distance running in?
What would the ideal running footwear look like for running on sand for you?	How can I design the perfect sand running shoe for the demographic, based on aesthetic and performance wants and needs?

Time to complete survey: 5 minutes

Initial Testing Phase: Quantifying Design Considerations (January 14-21)

The initial testing phase will take place at the Oregon Coast at Cannon Beach, OR on dry sand. This is for testing on the sand environment for design considerations. The 4 baseline products with different aspects of performance will be tested. There will be a volunteer within the target athlete group, male 13-25, and with any running experience. The athlete will bring their own clothing to run in. The speed of the running will be low-intensity and self-determined by the athlete. The speed will be replicated in future testing to ensure consistency. The test will utilize a RunScribe sensor on both feet. Metrics that will be documented in this testing are pronation, contact time, and vertical ground reaction forces. These metrics will be averaged and there will be 3 trials total. The purpose of collecting these metrics is to find if there are movement patterns that occur, such as overpronation, high ground reaction forces, which would be a design consideration for the construction of the created footwear in how to prevent. For contact time, this metric will be utilized to quantify slipping or traction on the sand surface. If there is more contact time, there is more slipping on the sand. The averaged results will be compared to each other to find which baseline product provides less slipping or traction on the sand. For the subjective questionnaire metrics, rated perceived exertion and general comfort, these will be averaged, and will be design consideration to how to create the ideal sand running shoe.

Items to bring: baseline products, Runscribe sensor, paperwork, cones, GPS watch.

Professional Development

My top 5 strengths that were determined by the Strengths Finder survey are competition, achiever, activator, learner, and individualization (Rath, 2007). This project aligns well with my strengths and skill-set because it will involve some of these strengths to be applied first-hand. Individualization and learner will be two strengths that I believe will be shown as a major theme throughout the project. Individualization for the footwear I create to be specific to a demographic of people, and learner to be able to actively learn in my design process to eventually create a product that accomplishes what I am setting out to do. I aim to combine my knowledge in design and science to innovate in new spaces. I typically will think science-first, which allows me to hold myself accountable through objective thinking throughout my design process. This project will require a lot of testing and validation, which is in my educational background, and also require the knowledge to design, ideate, and prototype, which is what I have been learning from my education currently. This project will be a culmination of all of my education thus-far, and I aim to utilize my knowledge in both the science and design space to create a product that is a testament to my education.

I see this project aligning with my career goals in the sports product design industry, because my goal is to work in running footwear for a major company in the innovation space. This project is innovative in many senses, and I think will give me the perspective of what it is like to work in this area of sports product design. One career in the sportswear industry that I am interested in is wear testing, and I think that the testing and validation to my project will allow me to understand more aspects of wear testing on the prototype footwear that I create, in order to prepare me for a career in wear testing. My project mentor moving forward will be Ryan Foust from Bass Pro Shops, who works in footwear design.

Golden Circle
Why: To make footwear that can inspire a generation of runners in the Marshall Islands

How: Using exercise science ideologies and story-telling to create impactful footwear

What: Running footwear that is built for the beach and hot and humid climate

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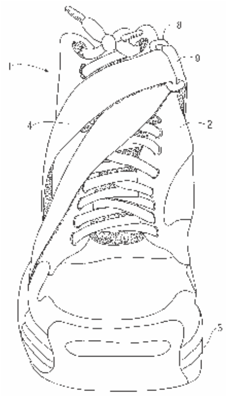
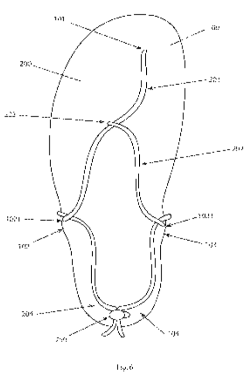
Appendix A – Patents



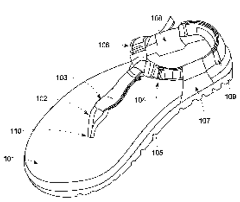
Shoe, ankle orthosis and method for protecting the ankle (US6270468B1)

- Protects the person's subtalar joint against inversion during walking, running or jumping
- Eliminates or reduces shoe rollover and inversion ankle injury
- Doesn't restrict normal motion of the foot during gait, running and jumping
- Orthopaedic device incorporated in athletic footwear that supports ankle joint



Sandal strap arrangement and tensioning system (US9635899B2)

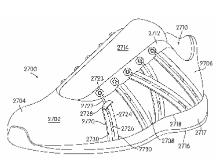
- Sandal has two independent support straps that are joined over the metatarsal region of the foot
- Straps have tension for foot lock-down



Sport Sandal with Y-Strap (US20220007779A1)

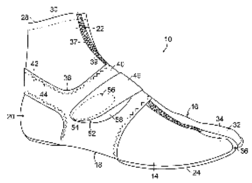
- Y-strap sandal with a G-hook and G-hook strap system to secure the foot
- Strap system is attached to a hard rubber sole

Tendon assembly for an article of footwear (EP2670269B1)



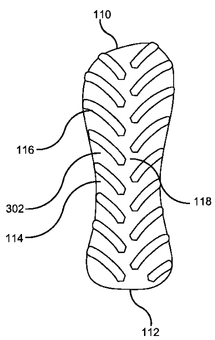
- Upper consists of tendons that serve to secure the foot
- Tendons have a fastening system to tighten the footwear
- Tendons can provide an aspect of stability

Article of footwear for sand sports (US7082703B2)



- Upper has a two toe pockets or toe-spreaders for hygienic purposes
- Strap on upper secures the foot and provides stability
- Outsole has cleats oriented for performance in the sand

Article of Footwear for Sand Surfaces (US20220322783A1)

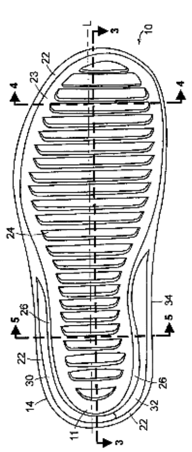


• Outsole has a pair of longitudinal edges, a longitudinal axis of the bottom surface, two sets of parallel lugs to reduce slipping and provide stability on the sand
• Footwear is a sandal, with straps that are inter-woven sewn or glued to the insole

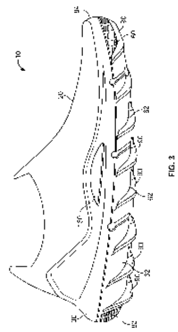
Footwear with sucker-type protrusions for sand protection (JP3152661U)

Footwear has a sand removal function, air permeability and water permeability
Suction cup protrusions, such as craters, are attached to the bottom of the footwear
Suction cup serves the purpose of making walking on sand easier, and restricting sand from entering the footwear

Sole for article of footwear for granular surfaces (US7204044B2)

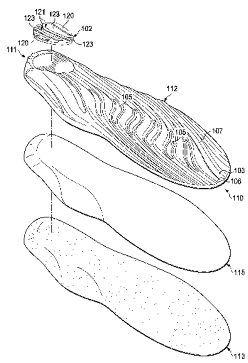


- Footwear for granular surfaces such as sand or gravel
- A peripheral lip projecting downwardly and outwardly from the lower surface and extending about the entire periphery of the lower surface;
- A plurality of fins projecting downwardly from the lower surface, at least some of the fins angled rearwardly from the lower surface, and at least some of the fins extending transversely across substantially an entire width of the lower surface; and
- An inner lip projecting downwardly and outwardly from the lower surface and spaced inwardly of the peripheral lip such that a recess is formed between the peripheral lip and the inner lip, the inner lip extending around a heel portion of the sole.



Footwear with pontoon sole structure (US20140259784A1)

- Pontoons flex to increase the surface area, reducing the sinking of the footwear in loose ground
- Pontoons are hollow, tube-like members



Flow insole (US10010131B2)

- Insole generates air flow during use to assist in cooling or warming of the foot
- Air flows to the plantar surface of the foot to promote cooling in a high sweat zone
- Heel pad is incorporated into the insole

Footwear cooling system (US8191284B2)

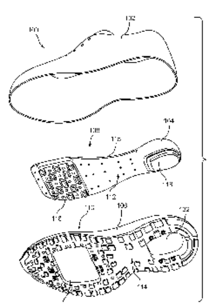
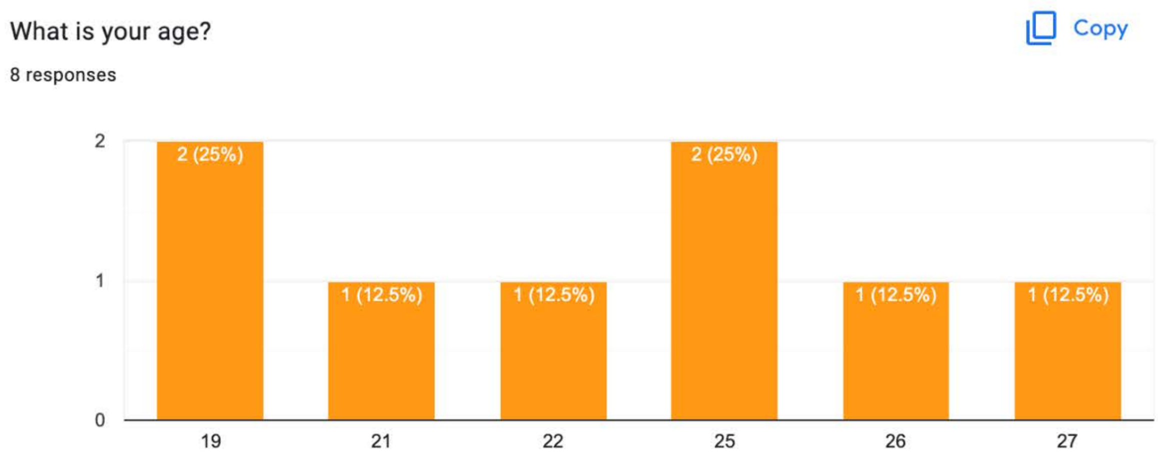
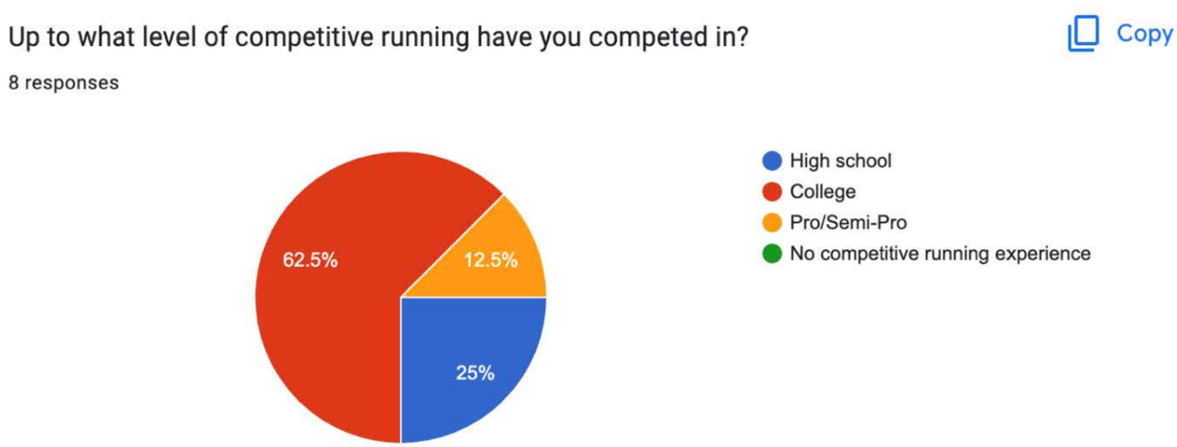


FIG. 1

- 2 compression chambers that compress during motion
- First compression chamber and second compression chamber create a pressure imbalance that creates an exchange of air through the footwear

Appendix B -- Athlete Insights





Have you experienced any injuries from running?

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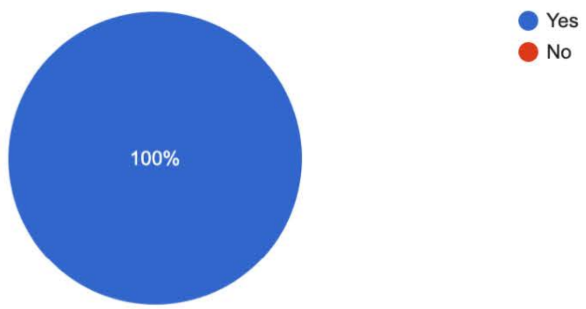
8 responses



If yes, what injuries have you had?

8 responses

Patellar Tendonitis, shin splints, plantar fasciitis

Tibial fracture, tendinitis in ankle and knee

IT band syndrome, shin splints, plantar fasciitis

Patella tendonitis

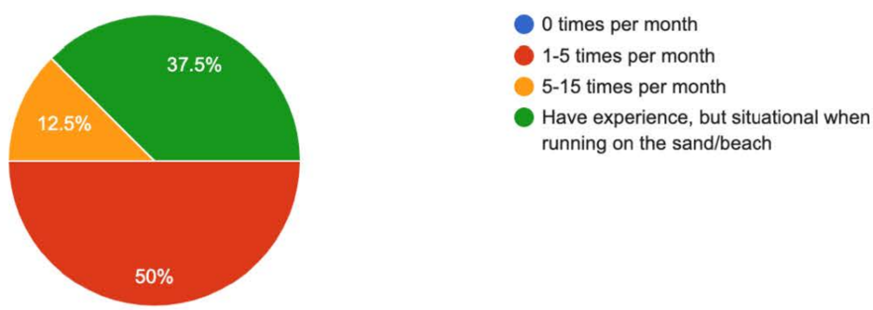
Knee stuff usually, patellar tendinitis and IT band

Ankle Tendinitis, now arthritis

Patella tendinitis

On average, how often do you run on the sand or beach environment?

8 responses



Why do you choose to train on the sand/beach?

8 responses

Change of scenery, it is more challenging, less stress on the joints, different muscle activation, and it's different than other types of running

Relaxing and soft surface

Ocean breeze, easy on body

Scenic and not as boring as other running

Close proximity and it's relaxing

More entertaining than the roads

I don't get to do it where I live normally, so it's a good change

Change of pace

How would you describe the main differences between running on the sand/beach compared to other overground surfaces?

8 responses

Running on the sand is more difficult on average. I train sometimes in shoes and sometimes barefoot depending on what I want out of it, such as just logging miles on soft surface, or if I want to just relax and get different muscles activated in a nice area. Sand has more slippage in trainers than other surfaces in shoes, but barefoot doesn't have as much slippage. Sand is softer than a lot of other surfaces so it's a nice change of pace for the body

Sand/beach is harder than other surfaces to run fast. I try to only run on it when I want soft surface and run barefoot. Trainers slide too much and it's not always enjoyable

Sand running is more challenging than a lot of other surfaces I run on. Soft, not quite as soft as dirt, but nice on the joints compared to concrete or asphalt. Don't need shoes usually, and it's actually better when I don't wear them. Each step the ground moves so it's challenging on the muscles.

The sand is harder to grip and running shoes slide around. It is softer than a lot of other surfaces, but depends on the sand too

The sand can be more difficult than other surfaces. It doesn't have "give" like concrete, so you slide a lot more in trainers. It is soft, but every step is more challenging than a soft surface like grass or dirt

Sand is harder to train on, but easier on the body. Sliding each step, so fast running isn't feasible like other surfaces.

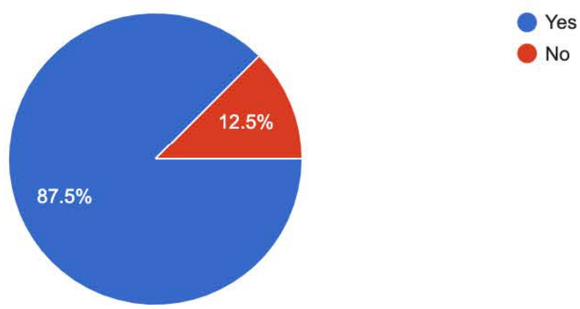
You slide a lot on sand compared to other surfaces, and you get tired a lot more easily.

It's a lot more difficult, which is why I don't do it too often. Running fast is not possible and you're more likely to be sore in unusual ways.

Does your footwear choice change when running in the sand or beach environment? (changing which running shoe you use, or going barefoot)

Copy

8 responses



If yes, what is the change? and why?

7 responses

Sometimes I run barefoot for less slippage, more/different muscle activation

Barefoot usually

Barefoot always

I run barefoot if I do run on sand

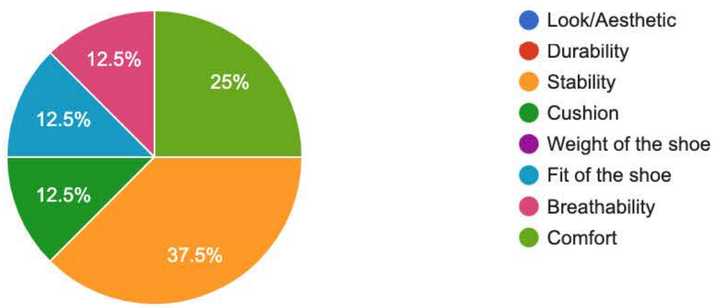
Sometimes barefoot, but only for a couple miles

Sometimes no shoes

Going barefoot to reduce slipping

What do you look for the most when choosing your running training shoes, or your daily trainer?

8 responses



When normally training for running, do you wear additional equipment or gear other than trainers? (brace, orthotic, etc.). If so, what is it and why?

5 responses

No

Shoe inserts for more cushion

No

No I don't.

If you answered yes to the last question, how do you accommodate for this when running on the sand/beach?

1 response

I either wear them in the shoes when I do wear shoes, or I just run slow casual miles barefoot and I don't mind

Have you suffered type of injury from training on the sand/beach? If so, what was it?

8 responses

Yes, soft tissue blistering. My ankles are sore the next day if I run 5+ miles

Yes, blisters

Blisters

Small ankle sprain

Blood blister

Blisters, extreme soreness

No

Soreness.

Any additional comments/concerns for sand/beach running

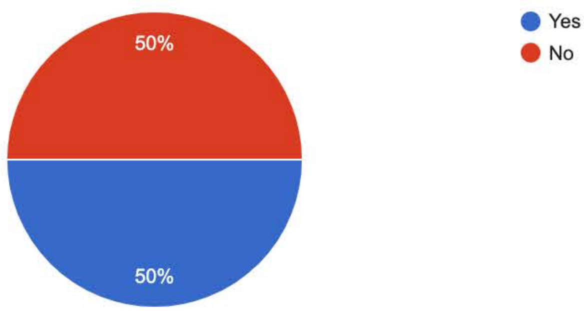
I can't run consecutive days on the sand because of soreness in ankles and muscles. Would be cool to see something that can help minimize that.

I think ankle stability in sand is the worst part the next day.

Have you experienced problems or injuries in athletes that have occurred from training at the beach or in the sand environment?

Copy

2 responses



If YES, what problems have you experienced, and what type of rehab/prevention do you use for these problems or injuries?

2 responses

Usually soft tissue injuries like abrasions or blisters. No rehab, but cleaning the wound and protecting it so the athlete can run again.

I haven't experienced anything yet as an athletic training student, but I can imagine soft tissue injuries from running barefoot. Ankle stability and how it affects the knee and hip joint as well could be a problem.

Part II: Project Development

Term Goals

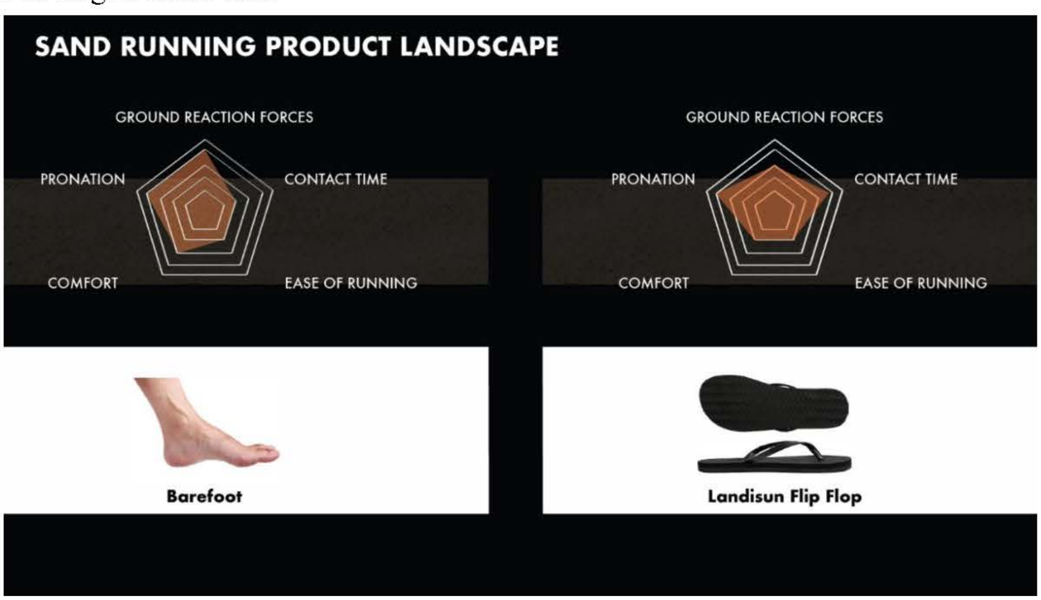
The goal for the second term of this project will look to go from background research to physical design. At the end of the term, a proof of concept will be presented to show that the initial research conducted as well as the physical research and development prove that the project is feasible. The physical research and development will include materials exploration, benchmark testing, ideation, and validation through final product testing.

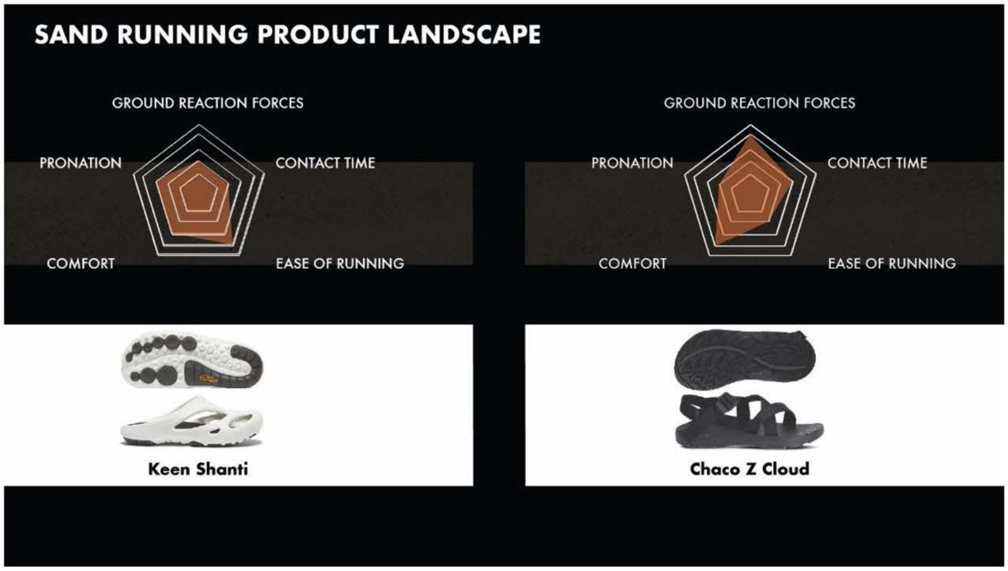
Benchmark Testing

The initial benchmark testing was to be completed with bare feet and the Landisun Flip-Flop to accommodate the Marshallese open-toed culture and based on the research on what is currently worn in the Marshall Islands. 2 more footwear options were added in the second term of this project, in order to have a goal or reference for testing results for the final created product. The two added footwear products are the Keen Shanti and the Chaco Z Cloud.

The Keen Shanti has a footbed for cushioning, and also circular lugs on the bottom. The footbed was speculated in the design process to potentially offer more cushioning and reduce the vertical ground reaction forces, a main metric that is being used for success in this project. This is because the current landscape for sandals does not have a large amount of sandals that include a separated footbed, and if the results were positive, this would offer a new design consideration for the final product. The circular lugs were speculated to offer more surface area to land and take off from during the running gait cycle. In an unstable surface such as sand, a larger surface area is wanted, rather than thinner elements of traction that dig in and move with the sand. This was to be tested with the contact time metric to find design considerations to move forward with. The Chaco Z Cloud was looked at for its straps that offer many elements of stability and foot lockdown. The metrics to be looked at mainly here for design considerations were pronation excursion and ground reaction forces.

The baseline testing was conducted on sand, and with a male athlete in the target user age range (13-25). The athlete used the RunScribe footpod sensor to run 400m intervals in sand at a set pace (7:00 per mile), in each of the baseline products. This was repeated 3 times and the metrics were averaged at the end.





The final results gave many design considerations to move forward with. After averaging all of the metrics and validating or dismissing the initial speculations through the data, 2 more metrics were added, ease of running and subjective comfort. These 2 metrics were added to provide more insight into the experience that the athlete had during this testing, in order to design for footwear that has metrics that are better than the baseline products that were tested, and also provide an experience that the runner enjoys. This way, the final design can include footwear that is practical and enjoyable. The averaged objective metrics and the subjective metrics were put into a graph to simplify the results.

To summarize the results of this testing, the barefoot testing had high numbers of vertical ground reaction forces, high degrees of pronation excursion, and low contact time. The user felt that the barefoot testing was uncomfortable, due to abrasion from the sand and no traction at all in the sand, which made the ease of running very low.

The flip-flop testing had low numbers of vertical ground reaction forces, high degrees of pronation excursion, and high contact time. The user felt that the flip-flop testing was uncomfortable, due to the inconsistency of every step, which didn't allow for the user to "get into a rhythym." The user found the flip-flop to no be easy to run in.

The Keen Shanti had low numbers of vertical ground reaction forces, high degrees of pronation excursion, and low contact time. The user felt that Keen Shanti had a very enjoyable experience in terms of comfort and ease of running, other than the fact that the sandal didn't have heel lock-down, which provided the only disliked area. The user provided feedback to attempt to utilize the main benefits of the Keen Shanti sandal, such as the traction and footbed.

The Chaco Z Cloud testing had high numbers of vertical ground reaction forces, low degrees of pronation excursion, and high contact time. The user had an unenjoyable experience in this sandal, due to its high midsole profile, high weight, low cushioning, and the traction digging into the sand. The ease of running was very low for this reason, but the comfort was high due to the many aspects of foot lockdown.

Ideation and Prototyping

The RunScribe sensor and app provided many starting points for ideation for each aspect of the footwear, the upper, the midsole, and the outsole. A general plan was created based off of the insights and data collected from the baseline testing for design elements to move forward with.

BASELINE RESULTS OBJECTIVE METRICS

Major Takeaways:

- Keen Shanti has very low contact time, which means there could be a correlation of circular lugs providing more surface area during foot-strike to decrease time on ground in unstable sand.
- The Shanti also had the lowest GRF's which means there could also be a correlation for having a seperate insole for extra cushioning in performance sandals.
- Chaco Z Cloud had amazing numbers for pronation excursion (very low) so the foot lockdown should be considered.

Next steps with these considerations:

- Look to utilize circular lugs for low contact time.
- Create a zoned cushion system, building off of the Keen Shanti design (cushioning system that utilizes softer insole material).
- Find ways to lock down the foot as secure as the Chaco Z Cloud.

BASELINE RESULTS SUBJECTIVE METRICS

Pros/Cons

- Keen Shanti had the most enjoyable experience when running in sand because of its response when landing and taking off. It also was the most comfortable for cushioning. Not having heel support made the athlete grip the sandal manually to prevent slipping, which was unenjoyable.
- Chaco Z Cloud locked the foot in very well, but was very sluggish, heavy, and too high profile of a midsole.
- Barefoot was "light" so nothing to drag around in the moving surface. Each step felt different it was very difficult to keep a rhythm. It also was painful for shock absorption and skin abrasion.
- The Landisun Flip-Flop's main benefit was a low profile and a sole to protect the foot and shock absorption. No rhythm in running because it was difficult to keep the sandal locked into the same place each step.

What to take into my design (from athlete advice)

- Find a way to lock in the heel, the Keen Shanti was nice, but had to grip the foot manually to prevent slipping out.
- Use a lower profile of a midsole than the Chaco Z Cloud.
- Try to replicate the traction elements of the Keen Shanti.

BASELINE RESULTS

Look to utilize circular lugs for low contact time → Use outsole contact maps to find zoning for lug placement to optimize for the athlete

Create a zoned cushion system, building off of the Keen Shanti design (cushioning system that utilizes softer insole material). → Use insole contact maps and footstrike patterns to find where cushioning should be focused

Find ways to lock down the foot as secure as the Chaco Z Cloud. → Look to where the foot is locked down in the Z Cloud and find how to ideate my own design

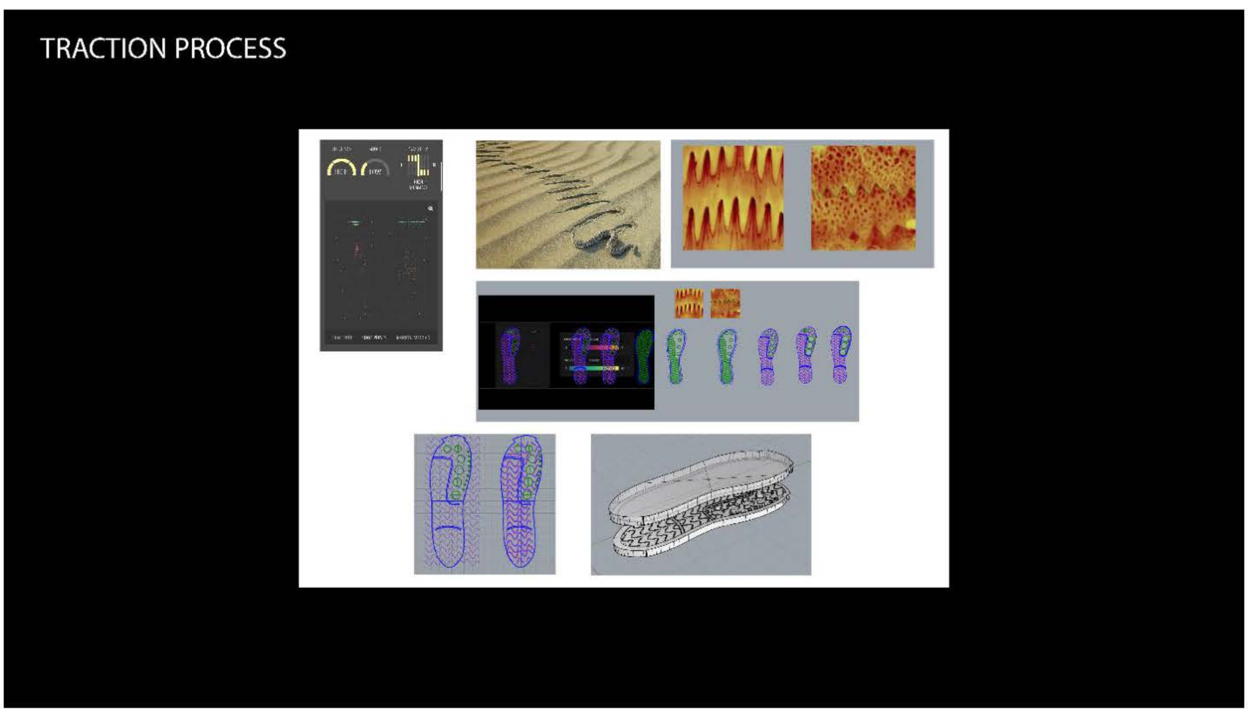
BASELINE RESULTS

Use outsole contact maps to find zoning for lug placement to optimize for the athlete →

this data shows the target athlete
on the lateral aspect of the foot at toe-off

Use insole contact maps and footstrike patterns to find where cushioning should be focused →

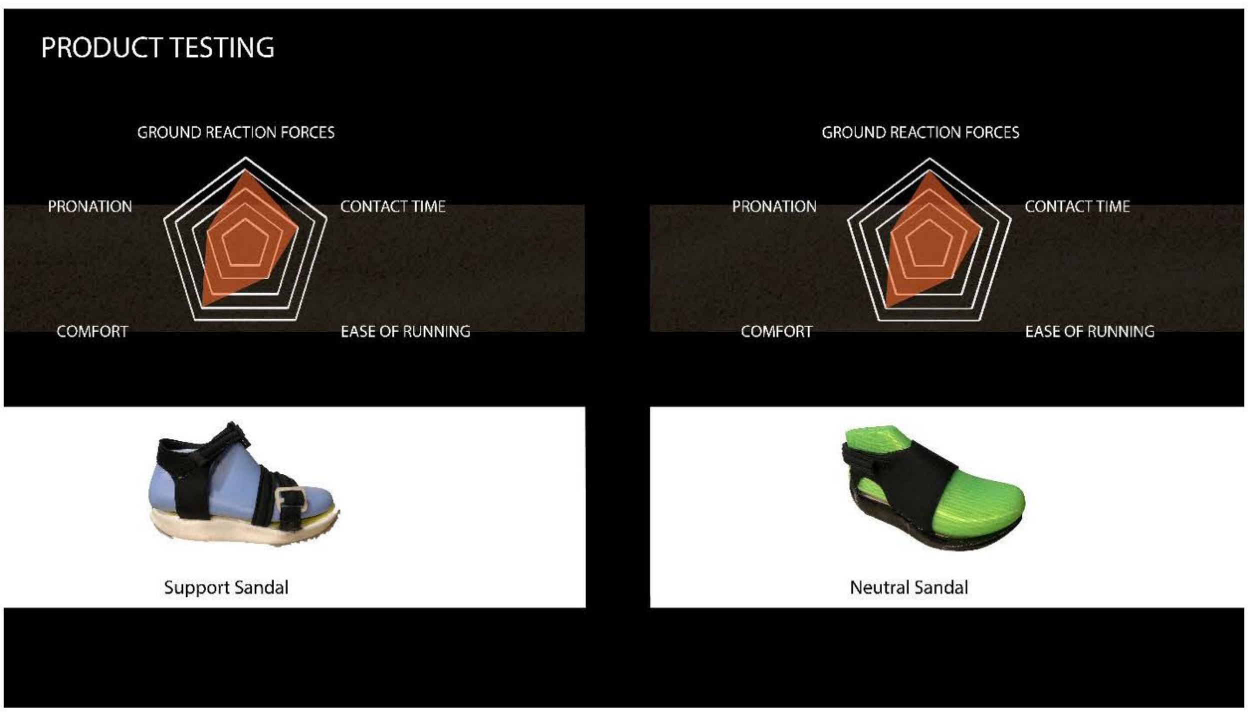
The outsole traction process started with taking data from the RunScribe app from the baseline testing, which included outsole print maps that showed where the athlete was landing and taking off during the running gait cycle. Based off of the specific areas where the athlete was landing, this map was taken into the 3D modeling software, Rhino, where the outsole map was converted into 2D linework. In the areas that the athlete was primarily landing on and taking off, circular lugs were placed to reflect the design insights and considerations from both objective and subjective metrics from the baseline testing. Past this, the rest of the traction looked to reflect slipping in the sagittal plane, where running biomechanics primarily lie. Horizontal lines are the simplest way to go about this, but design inspiration from biomimicry was used. The sidewinder snake, a snake that can reach speeds of up to 18 MPH in sand dunes was used as the inspiration of biomimicry. A microscopic look at the skin of this snake shows that its skin has wavy, horizontal protrusions (Elbein, 2021). This was taken into the design for the outsole for this sand running footwear, where pictures of the snake's skin were converted into 2D linework and used in the traction pattern for the outsole. Many iterations were made using these two main design elements, and finally a final traction pattern was settled on, and a mold was created in 3D.

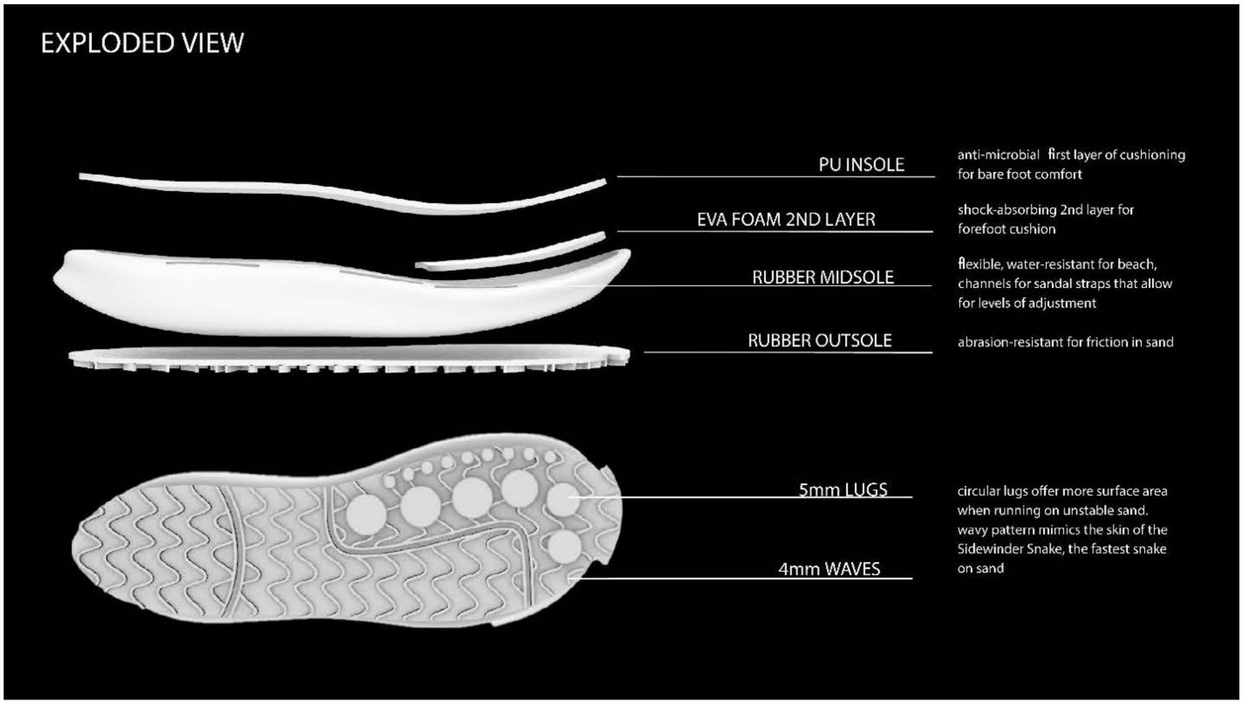


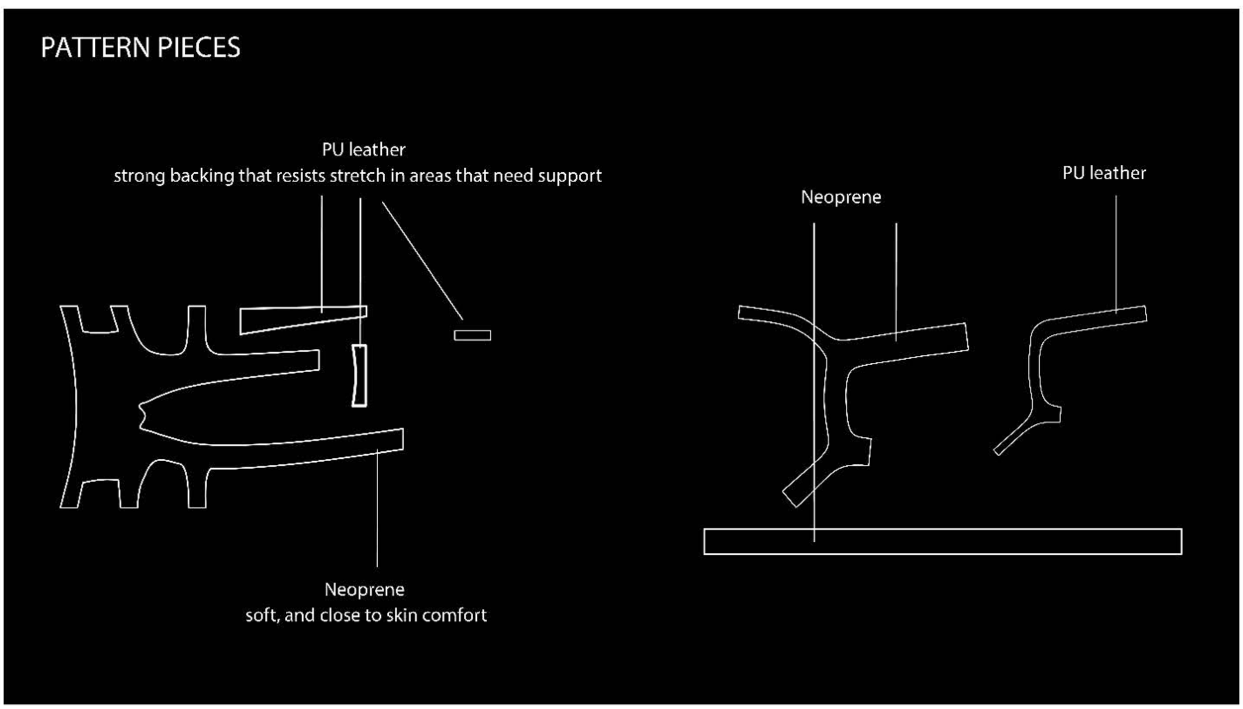
Validation Testing

The created footwear products were validated for a proof of concept by repeating the same general testing procedure as the baseline products. This was by running in the sand using the RunScribe sensor. Since the materials of the outsole and midsole are not the final materials, the current state of product testing as compared to the baselines are not to reflect the results that the final materials will provide. The current materials in the 2nd phase include 3D printed TPU midsole and outsole, which do not provide the performance aspects that the baseline products had. With this in mind, the 3 main testing points were subjective comfort, ease of running, and pronation excursion. The created footwear provided low degrees of pronation, comparable to the Chaco Z Cloud, which proves the concept of stability and foot lockdown were accomplished through the upper designs. The user found the created footwear to be comfortable to the skin, and the insole to provide ample cushioning. The user found the product to be easy to run in because of the elements of traction and foot lockdown.

Moving forward, this product will be recreated using rubber or foam for the printed materials, which will provide ample cushioning and show the ground reaction force and contact time metrics on an accurate scale.




EXPLODED VIEW
PU INSOLE
anti-microbial first layer of cushioning for bare foot comfort
EVA FOAM 2ND LAYER
shock-absorbing 2nd layer for forefoot cushion
RUBBER MIDSOLE
flexible, water-resistant for beach, channels for sandal straps that allow for levels of adjustment
RUBBER OUTSOLE
abrasion-resistant for friction in sand
5mm LUGS
4mm WAVES
circular lugs offer more surface area when running on unstable sand. wavy pattern mimics the skin of the Sidewinder Snake, the fastest snake on sand


PATTERN PIECES
PU leather
strong backing that resists stretch in areas that need support
Neoprene
soft, and close to skin comfort
Neoprene
PU leather

Part III: Product Creation and Validation

At the end of the previous term, the project had two different upper silhouettes, but not enough major differing performance benefits between the two footwear models. The start of the next phase was to start with developing main differences between the two sandal options to differentiate high performance and recovery. The two sandal uppers were also looked at in order to ideate and prototype to further push the limits of the design, using athlete feedback and aesthetic purpose. The main goal of this term was to develop two different effective sandals that provided two different training purposes in the sand.

Utilizing input from the previous review, the initial design process for these two sandals were furthered by sketching over pictures of the previously created prototypes in order to simplify small differences. The uppers for both of the sandals utilized hardware in order to lock down the foot and provide adjustability for the user. This posed concerns for the user, as the hardware could by limiting for comfort and also performance during running gait. The general shape and morphology of the midsole was also ideated and sketched on to improve for both aesthetic and performance purposes.

The tooling for both of the created sandals at the end of the previous term were the same and included channels that ran through the side wall of the midsole, inspired by one of the baseline products, the Chaco Z Cloud. The manufacturing of the upper and its interaction with these channels provided a lot of difficulty, so the initial goal of the term for the tooling was to find how to incorporate a new system for the uppers to interact with the rest of the sandal. Past this, finding how to create different performance benefits and cushioning was the main goal of the term. The idea of incorporating a carbon fiber plate into the performance or speed sandal was a process that took place over the entire final term, and creating a unique shape, curve profile, and finding how to mold the plate into the midsole was ideated and prototyped. Finally, the goal of creating a cushioning system for both sandal with the demands of performance with a carbon fiber plate, and also for cushioning for an everyday trainer was ideated and prototyped.

The collection name, Ettōr, was created in the previous term as well. This word goes to the Marshallese origins of the project and means to run or running in Marshallese. The two sandals created were named the Ettōr Speed Sandal and the Ettōr Recovery Sandal.

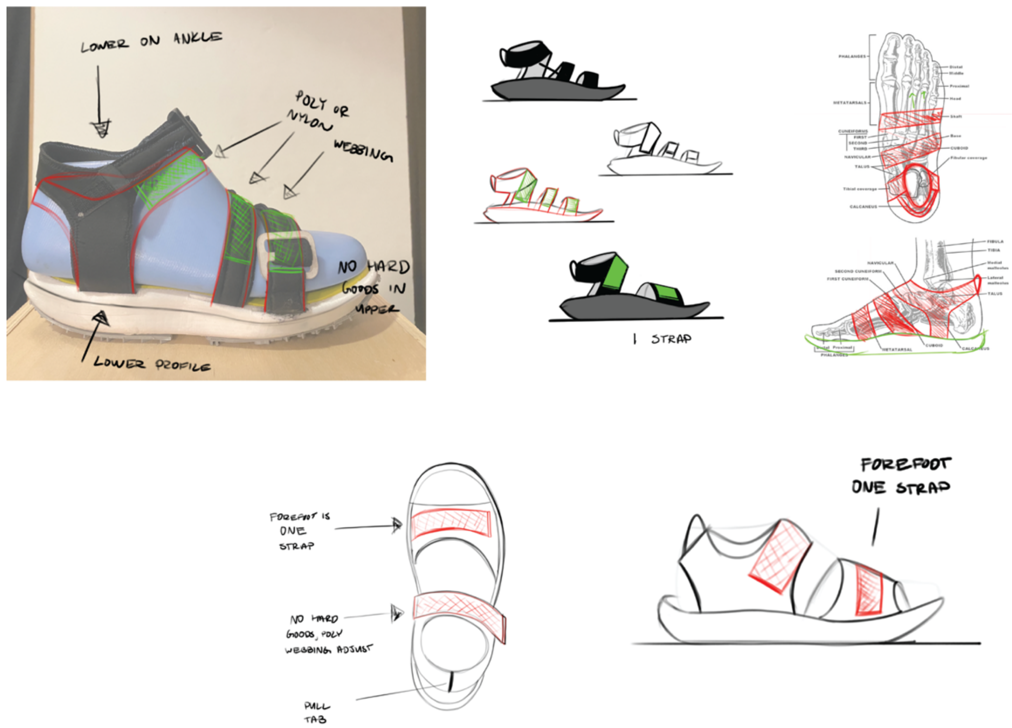


Figure 14

Initial Ideation for Speed Sandal (Rehm, 2023)

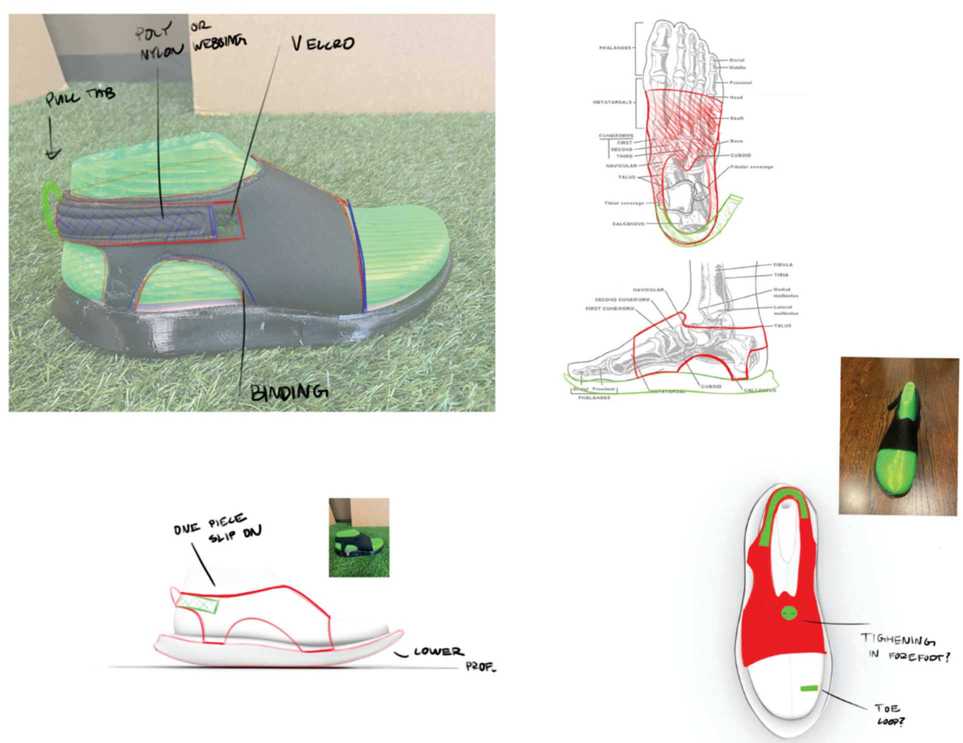


Figure 15

Initial Ideation for Recovery Sandal (Rehm, 2023)

3D CAD Ideation and Prototyping

Starting with the previous midsole created, this model was altered in order to find new ways of inserting the upper into the midsole unit. The midsole modeled in Rhino 7 was altered and refined aesthetically, and a PETG filament mold was 3D printed in order to physically prototype with cushioning and upper patterns. The main difference from the previous midsole was a cutout for the upper to lay in that were located underneath the footbed recess. This allowed the upper pattern to be cemented into the midsole without the difficult manufacturing process that the side wall channels previously had. Utilizing the new midsole, upper pattern pieces could be easier created and prototyped using the dimensions of the recesses underneath the footbed.

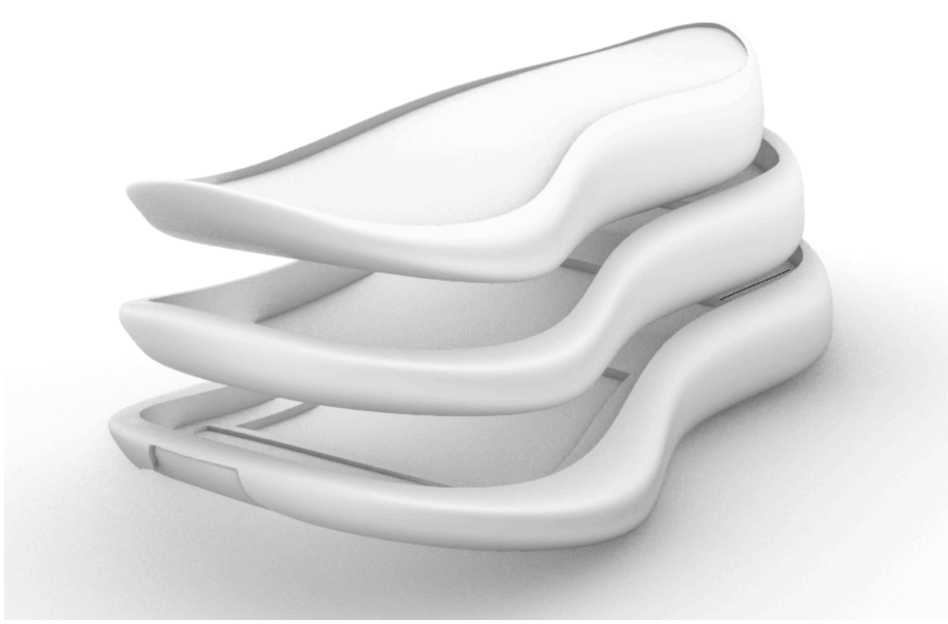


Figure 16

Midsole Morphology Perspective View (Rehm, 2023)

The midsole models in the Rhino 7 CAD render above shows the difference in morphology from the previous term to the final iteration. The top model was the previous term's midsole, which was the narrowest and offered little support in the forefoot. The next iteration, the middle, was the first midsole model created in the final term for prototyping. This midsole model was wider than the previous model and had recesses for the upper located underneath the footbed. The bottom or final iteration was the widest of the models created, which was decided on to disperse the pressure of running in the sand with a larger surface area. The recesses created for the upper matched the middle or previous model in order to have the upper fit the user, but still offering a large surface area to disperse the pressures in the moving sand surface.

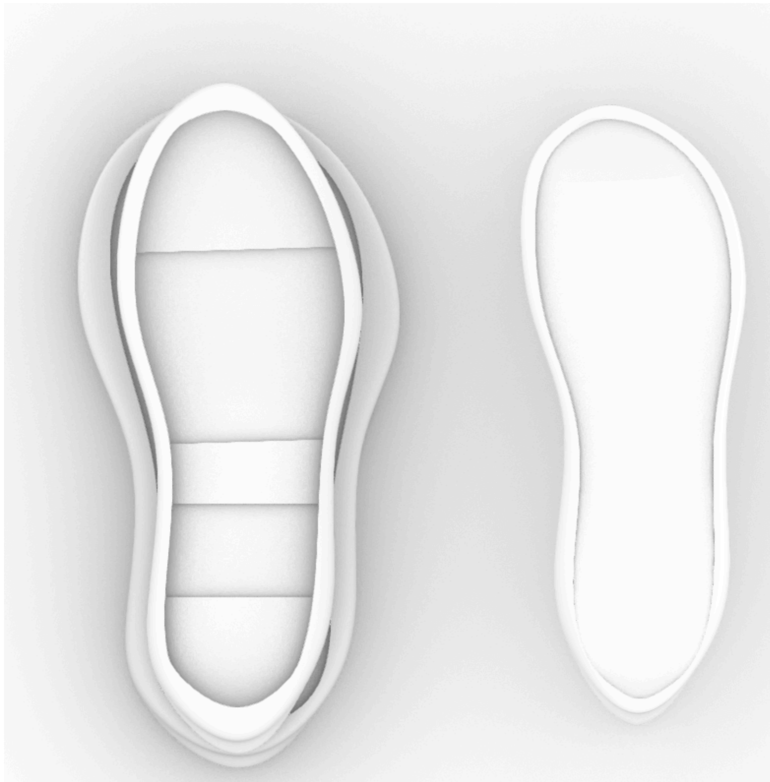


Figure 17

Midsole Morphology Top View (Rehm, 2023)

Figure 18

Cushioning and Outsole Recesses (Rehm, 2023)

Cushioning systems could also be prototyped with the recesses created for the footbed and on the bottom of the midsole above the outsole unit. A memory foam was initially used before using an Ortholite foam that was bonded to PU foam to create dual-density footbed for shock absorption. The cushioning located above the outsole unit was created for more shock-absorption within the midsole unit. During the creation of the carbon fiber plate and molding process, the stiffness offered discomfort, and adding specific cushioning above and below the carbon fiber plate was found to provide the most comfort.

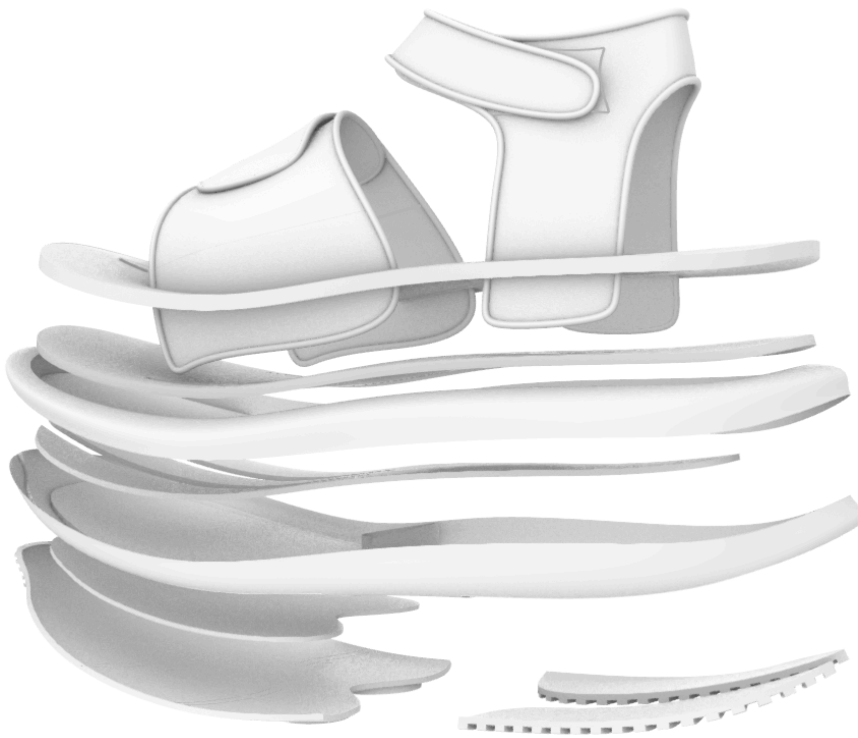


Figure 19

CAD Exploded View Cushioning System (Rehm, 2023)

The system modeled above shows multiple levels of cushioning located above and below the carbon fiber plate, offering ample cushioning and performance benefit with the carbon fiber propulsion plate. The use of Rhino 7 CAD iterating allowed for a perspective of how the construction of the sandal can be altered and quickly prototyped in combination with laser cutting the 2D linework and testing the cushioning units with the physical midsole created from a 3D printed mold.

Physical Creation Processes

The physical creation and iterating process allowed for user feedback and surface level decision making. Utilizing the 3D printed molds for the midsole and outsole units, the material decisions were fit into the designed recesses in order to create fully working prototypes. Some of the making processes are documented below.

Midsole

Figure 20

Midsole Foam Pour Into 3D Printed Mold (Rehm, 2023)

After creation of the midsole mold, mold-making foam was poured into the mold. The carbon fiber plate created was inserted half-way through the molding pour process to mold the carbon fiber plate into the midsole.

Outsole

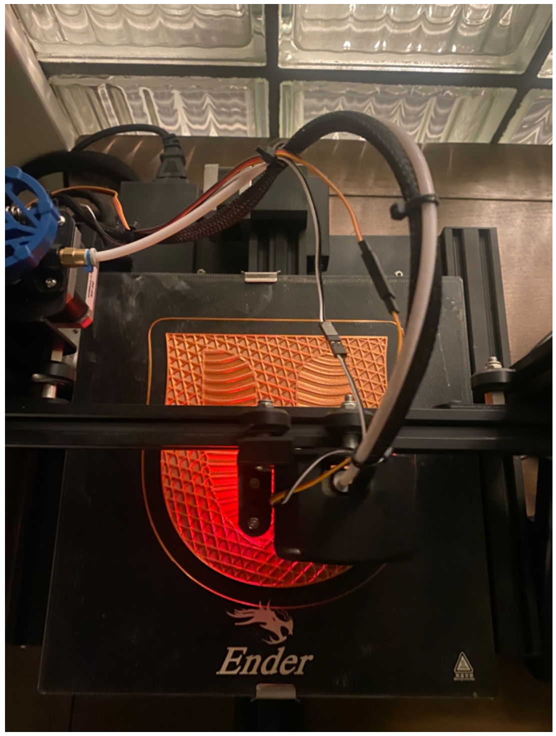


Figure 21

3D Printing Mold Pieces (Rehm, 2023)

Figure 22

Outsole Pouring (Rehm, 2023)

Figure 23

Outsole Forefoot
(Rehm, 2023)

After the creation of the 3D printed outsole molds, rubber was poured into the mold and cured to create the outsole units.

Carbon Fiber Plate

Figure 24

Carbon Fiber Plate Materials (Rehm, 2023)

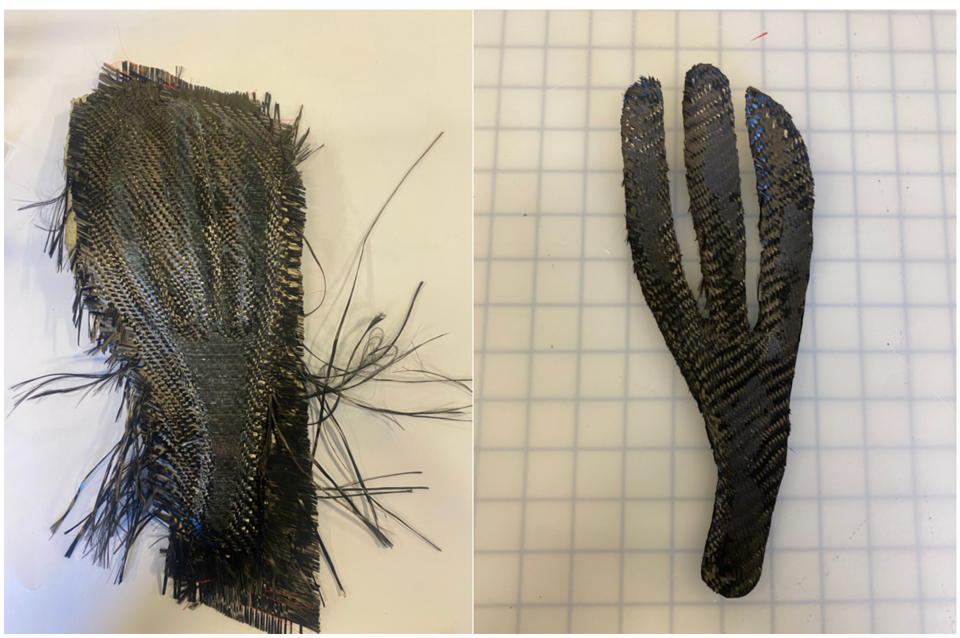


Figure 25

Trimming the plate from mold creation (Rehm, 2023)

The carbon fiber plate was created using carbon fiber fabric, epoxy resin and epoxy hardener. The composition of the plate was 3 layers of carbon fiber fabric laid in alternating directions, the top and bottom layer laid in a vertical orientation, to create stiffness in the sagittal plane. The epoxy resin and hardener were brushed on each layer to create stiffness in the carbon fiber. After curing, the resulting carbon fiber unit was trimmed down using scissors, a hacksaw, and sanded down with a Dremel. The process took 3 hours post-cure and required a respirator mask and a well-ventilated space.

Upper

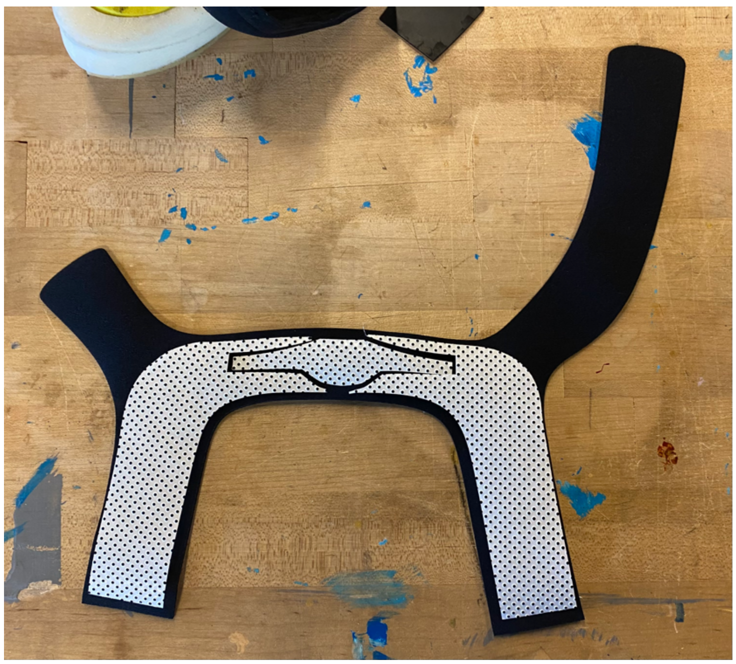


Figure 26

Upper Construction, laser cut and adhesive
(Rehm, 2023)

Figure 27

Upper Construction, Sewing (Rehm, 2023)

The upper was created using patterns from 2D linework in Rhino 7 and Adobe Illustrator. The patterns were cut out with a laser cutter and bonded together with different zones of cushioning and support using BEMIS adhesive paper and a heat press. After the bonding process, the edges of the upper pieces were finished by sewing an elastic binding tape.

Cushioning Systems

Figure 28

Final Footbed (Rehm, 2023)

Figure 29

Cushioning units rendered in Rhino 7 (Rehm, 2023)

The footbed creation consisted of laser cutting Ortholite foam and closed cell PU foam using the 3D midsole model, and 2D linework for cut outs for the upper insertion. The two foams were bonded together using adhesive BEMIS paper and heat pressed. Then, the individual open cell EVA cushioning units in the footbed were laser cut and bonded with BEMIS adhesive and the heat press, to create the footbed cushioning system. Finally, on top of the top insole cushioning units, a knit polyester fabric was bonded to create an insole with zoned cushioning and comfort to skin. All cushioning units were laser cut and specified from the Rhino 7 midsole model recesses. The uppers created were fit into the footbed upper cut-outs and cemented into the midsole recesses created for the upper and footbed. The forefoot cushioning unit that was inserted above the outsole and underneath the carbon fiber plate was laser cut using 2D linework extracted from the 3D midsole model.

Final Design

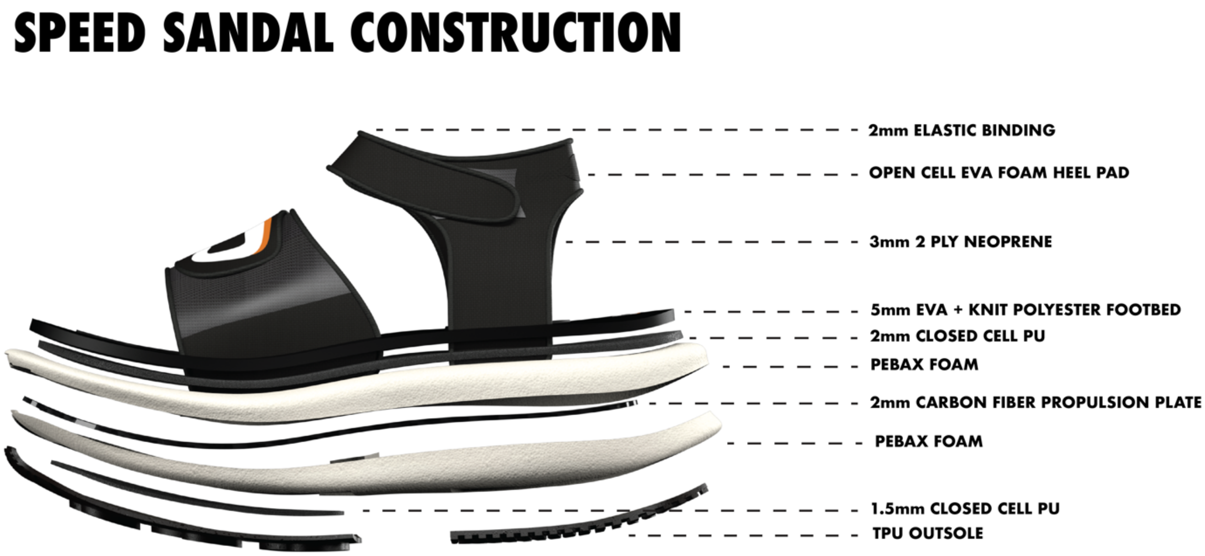


Figure 30

Speed Sandal render (Rehm, 2023)

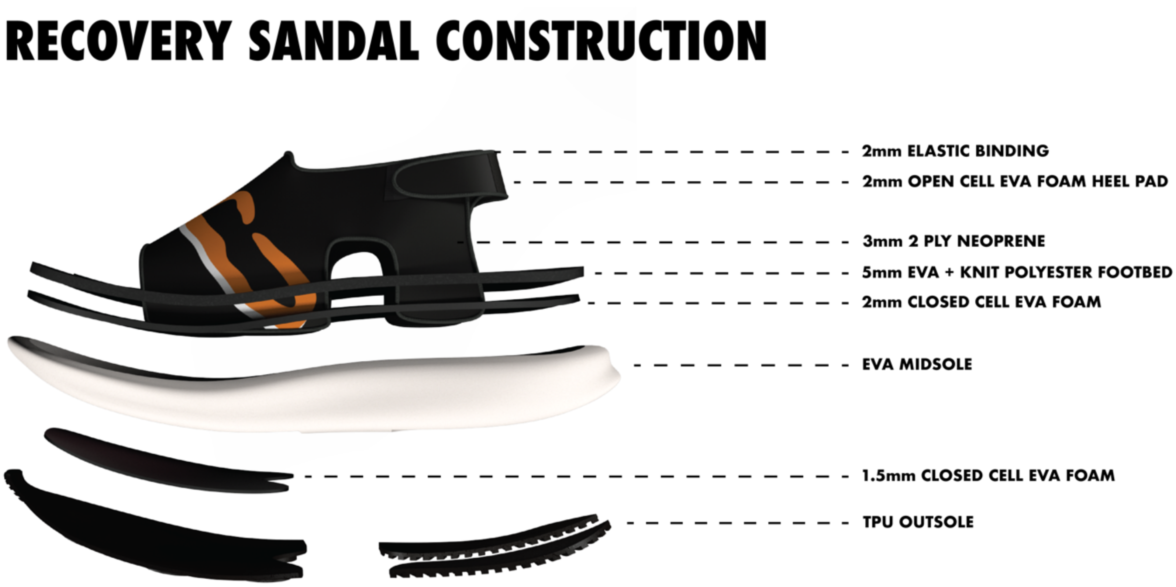


Figure 31

*Recovery sandal render (*Rehm, 2023)

Final Prototypes

Figure 32

Speed Sandal final prototype (Rehm, 2023)

Figure 33

Speed Sandal final prototype (Rehm, 2023)

Testing and Validation

Testing for the two sandals included replicating the baseline testing, which was running 4x200m on dry sand. Since 2 left sandals were created, the right foot could wear each of the baseline products to compare directly with the data from the Runscribe sensor at the same effort. The Runscribe sensor includes a left and right sensor, so the baselines could be worn and tested at the same time. The objective metrics measured were consistent to the initial baseline testing, including vertical GRFs, contact time, and pronation excursion. The subjective metrics measured were RPE and general comfort (scale of 1-5).

Successful validation for vertical GRFs was to be lower than all baseline products, for contact time to be lower than all baseline products, and for pronation to fall in the range below over-pronation, or not have degrees of over-pronation (over 15 degrees). These metrics will show that the final products created have high performance and injury prevention, compared to the baseline competitors, which was the goal of the project. For the subjective metrics, RPE should be lower than the baseline products and general comfort should be lower as well. These metrics show more of a general running experience in sand and how perception of difficulty and comfort can impact running performance and enjoyment. The objective of the performance sandal was to have the lowest contact time and the low RPE and comfort while protecting against over-pronation and high levels of vertical ground reaction forces. The objective

The main metric for performance in sand was contact time. On average, the performance sandal had 317 ms of contact time per stride. The baseline products averaged 331 ms of contact time at the same effort. These averages were created after eliminating the furthest deviating numbers, or highest and lowest contact times for each product tested. This was done to provide more reliability in the data acquired from the sensor.

Contact Time

With the average contact times averaged, a generalized formula was created to show the difference in effort between the performance sandal and the baseline products (barefoot, flip-flop, Keen Shanti, and Chaco Z Cloud) tested. The formula took the average stride length of running, 3 feet, and the number of steps in a mile, 5280 feet. Then, the steps in a mile, 5280 feet, was divided by the average stride length, 3 feet, to find the number of steps in a mile, 1760 steps. The total time was calculated next by multiplying the average contact time per step acquired from the sensor data and multiplied by the number of steps in a mile, or 317 x 1760 (performance sandal) and 331 x 1760 (baseline averages). The total time for the performance sandal was 558,920 ms, or 558.92 seconds, or 9 minutes and 19 seconds per mile rounded. When using this formula for the average of the baselines, the total time was 582,160 ms, or 582.16 seconds, or 9 minutes and 42 seconds rounded. The total difference was 23 seconds per mile for the testing completed. The performance sandal was performing at a much higher level than the baselines tested in dry sand, at the same effort. The recovery sandal showed 325 ms of contact time average.

Vertical GRFs

The vertical GRFs of the performance and recovery sandal differed, the main difference between the two constructions being carbon fiber plate in the performance sandal. The RunScribe sensor uses Impact Gs as a metric to show the vertical component of Peak Gs. This correlates with the ground impact force experienced at footstrike. The typical range for Impact

Gs is between 5 Gs and 14 Gs. The average for the performance sandal was 9.4 Gs, and for the recovery sandal was 7.5 Gs. The average for the baseline products was 11.5 Gs, which shows that both of the sandals provided lower amount of ground impact force at footstrike than the baseline products tested. This metric shows that the two created sandals can prevent the risk of chronic injury from lower impact forces acting on the body.

Pronation

Pronation, according to the RunScribe sensor, has a typical range between -2 degrees and -20 degrees. Pronation is a necessary component to running, since it is a natural movement and means for shock absorption at footstrike. Over-pronation was what was designed against, since this is an un-natural movement that can pose more risk to injury. As previously defined, over-pronation is over 15 degrees of pronation. All of the tested products fell within the limits of normal pronation, meaning the created products had performance benefits and protection against high impact Gs, while also providing support at the ankle to further prevent the risk of injury. The highest amount of pronation deviation from the performance sandal was 10.3 degrees, and from the recovery sandal 4 degrees of deviation.

RPE

RPE, or rated perceived exertion, was taken on a scale of 1-5. The performance sandal received a score of 1, and the recovery sandal a score of 2. The baselines received the scores as follows: Keen Shanti, 2; Chaco Z Cloud, 5; barefoot 3; flip-flop 4. The perception of exertion for the sandals created showed a low level of effort to further back up the objective metrics measured above.

Comfort

Comfort was taken on a scale of 1-5. This metric was taken to put into perspective how the baseline and created products can sometimes offer high levels of performance, but low levels of comfort, which was against the goal of the design. In the testing completed, this was exhibited with the barefoot testing. Barefoot running in the sand showed low levels of contact time, but also low levels of comfort (1 on the 1-5 scale). This was due to abrasion to the skin and low levels of protection from impact. The other tested products metrics are as follows: performance sandal, 3; recovery sandal, 5; flip-flop, 1; Chaco Z Cloud, 2. These metrics further validate the experience of sand running with the created products, as RPE and comfort both are complementary to the objective metrics taken.

Figure 34 & 35

Testing Protocol, attaching the sensors to sandals (Rehm, 2023)

Figure 36

Subjective testing without sensors (Rehm, 2023)

FINAL PRESENTATION

Below is the final presentation for Ettōr, a collection created for sand, beach running environments and inspired by the Majuro Track and Field Stadium opening in the Marshall Islands. This collection offers two sandals of performance and recovery purposes, in order to increase the experience in sand. The two sandals are the Ettōr Speed Sandal and the Ettōr Recovery Sandal. The design of the project was inspired by exercise science concepts in order to increase performance metrics and reduce the risk of injury, while also creating a running experience in the sand that is higher than any other product on the market. Design processes and general project research are shown below.

THE MARSHALL ISLANDS

POPULATION:
60,000 PEOPLE

CLIMATE:
AVG. 82 F, HIGH HUMIDITY

TERRAIN:
PRIMARILY SAND

70 SQ. MILES OF TOTAL LAND
230 MI. OF SANDY COASTLINE

MARSHALLESE PEOPLE

AVERAGE AGE:
23.8 YEARS OLD

MALE TO FEMALE RATIO:
1.05:1

OPEN-TOED CULTURE

"I WEAR FLIP-FLOPS ALL WINTER. IT'S MY MARSHALLESE CULTURE."

CYNTHIA RIKLON

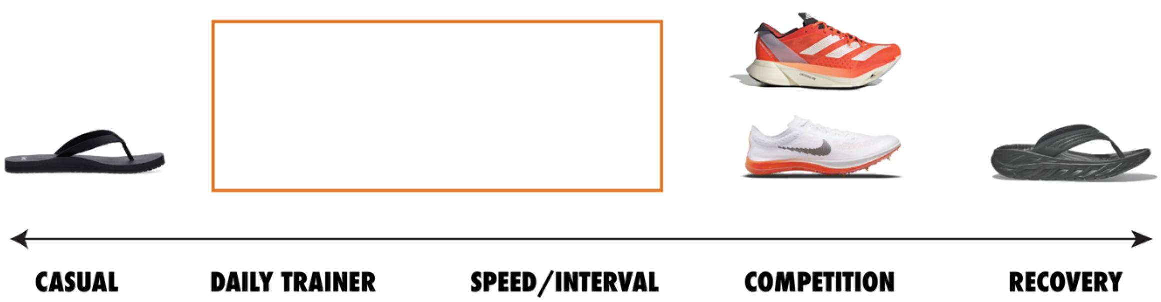
A TRACK AND FIELD STADIUM WILL BE BUILT FOR SUMMER 2024

MAJURO, THE MARSHALLESE CAPITAL, WILL HOST THE 2024 MICRONESIAN GAMES.

THERE IS CURRENTLY LITTLE TO NO ACCESS TO PUBLIC SPORTS FACILITIES. THIS STADIUM CAN PROVIDE AN OPPORTUNITY FOR SPORT.

WITH THE SANDY TERRAIN OF THE MARSHALL ISLANDS, THE MEANS OF TRAINING FOR USE OF THE STADIUM WILL BE A DAILY BARRIER.

BARRIER TO TRAINING FOR THE MICRONESIAN GAMES



THERE IS NO EXISTING RUNNING FOOTWEAR THAT IS OPTIMIZED FOR SAND RUNNING.

HOW CAN WE...

CREATE RUNNING FOOTWEAR FOR PEOPLE LOOKING TO TRAIN IN THE MARSHALL ISLANDS, OR OTHER SANDY BEACH ENVIRONMENTS, THAT IS OPTIMIZED FOR PERFORMANCE AND INJURY PREVENTION?

TARGET USER

MALE
AGE 13-25
ANY EXPERIENCE OF RUNNING
LIVES NEAR A SANDY BEACH

WITH THE TRACK AND FIELD STADIUM OPENING IN 2024, THIS DEMOGRAPHIC WILL BE THE FIRST TO FULLY UTILIZE THE STADIUM.

WHY IS RUNNING ON SAND MORE DIFFICULT?

SAND IS A MOVING SURFACE, REQUIRING EXTRA MECHANICAL WORK IN ORDER TO PROPEL FORWARDS WHEN THE FOOT SINKS.

EXTRA WORK REQUIRED FROM MUSCLES AND TENDONS CAN CAUSE CHRONIC INJURIES.

RUNNING ON SAND REQUIRES 1.6x MORE ENERGY EXPENDITURE THAN HARD SURFACES.

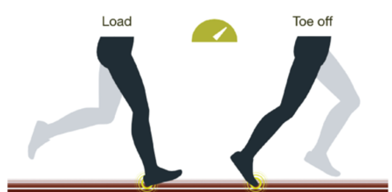
INITIAL TESTING: OBJECTIVE METRICS

ATHLETE RUNS 4X200m ON DRY SAND AT SET PACE USING A RUNSCRIBE FOOT-POD SENSOR

VERTICAL GRFs

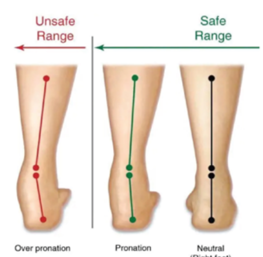
HIGHER GRFs, MORE RISK FOR CHRONIC SKELETAL INJURIES

CONTACT TIME



MORE CONTACT TIME, MORE ENERGY EXPENDITURE

PRONATION



OVER-PRONATION MEANS MORE RISK TO INJURY

INITIAL TESTING:
SUBJECTIVE METRICS

RATED PERCEIVED EXERTION

(1-5) DIFFICULTY OF RUNNING
IN THE SAND

COMFORT

(1-5) ALL ASPECTS OF THE
FOOTWEAR

CARBON FIBER PLATE

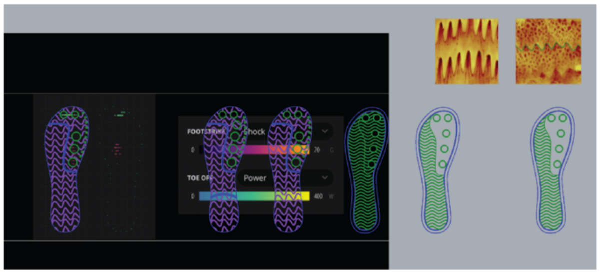
3D PRINT
(NOT STIFF)

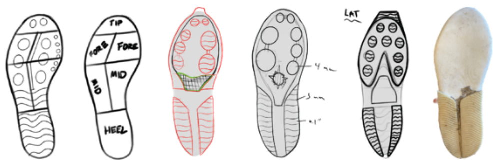
FROM MOLD

TRIMMED, STIFF

MOLDED INTO
MIDSOLE

OUTSOLE





CIRCULAR LUGS TO PROVIDE MORE SURFACE AREA DURING LANDING AND TOE OFF.

HORIZONTAL WAVES TO PREVENT SLIPPING IN THE SAGITTAL PLANE. INSPIRED BY THE SIDEWINDER SNAKE SKIN MICROGRAPH, THE FASTEST ANIMAL ON SAND.

MIDSOLE DEVELOPMENT

FORCE/AREA = PRESSURE

the larger the area, the smaller the pressure.

the smaller the area, the larger the pressure.

FOOTWEAR WITH SMALLER SURFACE AREA EXERT HIGHER PRESSURE AND DIG INTO THE SAND MORE. LESS PRESSURE AND MORE SURFACE AREA WILL DISPERSE THE PRESSURE, AND DIG IN LESS.

UPPER

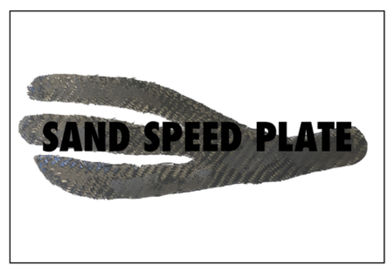
ETTŌR TECHNOLOGY

MIDSOLE OVER 1 INCH WIDER IN TOTAL WIDTH THAN STANDARD RUNNING SHOES, EASILY DISPLACING SAND

ZONED CUSHIONING BASED OFF OF INSOLE PRESSURE MAPS FROM SAND RUNNING TESTING

CIRCULAR LUGS ALLOW FOR MORE SURFACE AREA TO PUSH OFF AND LAND ON

LUGS STRATEGICALLY PLACED BASED ON OUTSOLE RIDE MAPS FROM SAND RUNNING TESTING. HORIZONTAL WAVES PREVENT SLIPPING DURING RUNNING.

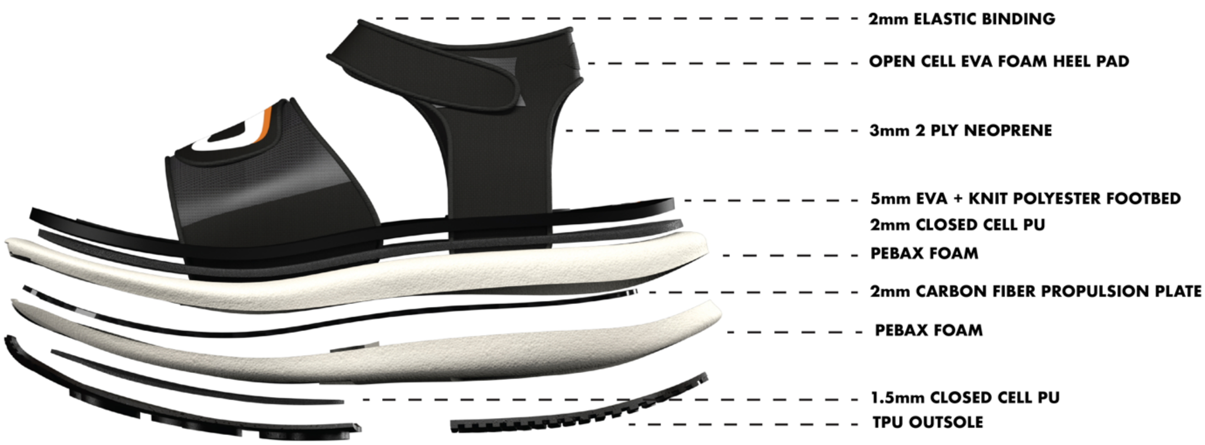


CARBON FIBER PLATE MOLDED INTO THE MIDSOLE, ALLOWING FOR AMPLE CUSHIONING IN A LOW PROFILE SILHOUETTE

3 PRONGED, FULL LENGTH CARBON FIBER PLATE FOR PROPULSION AND LESS MATERIAL WEIGHT

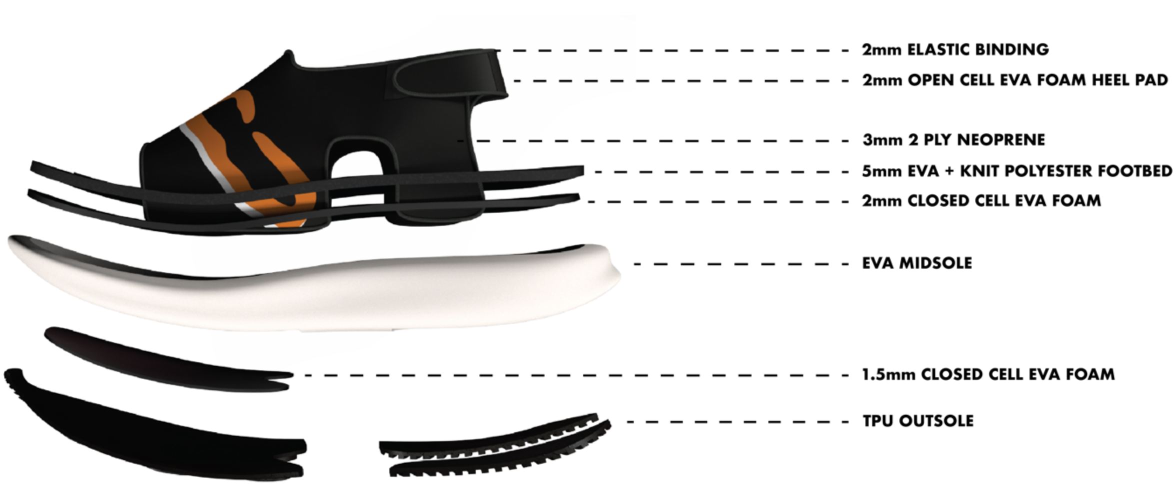
ETTŌR SPEED SANDAL

SPEED SANDAL CONSTRUCTION



ETTŌR RECOVERY SANDAL

RECOVERY SANDAL CONSTRUCTION



TESTING AVERAGES

CONTACT TIME: 316 ms

IMPACT Gs: 9.4 Gs

PRONATION EXCURSION:
NO OVER-PRONATION

BASELINE AVERAGES
331 ms
11.5 Gs
NO OVER-PRONATION

TESTING AVERAGES

CONTACT TIME: 325 ms

IMPACT Gs: 7.5 Gs

PRONATION EXCURSION:
NO OVER-PRONATION

BASELINE AVERAGES
331 ms
11.5 Gs
NO OVER-PRONATION

SAND EFFICIENCY

CONTACT TIME: 317 ms

AVERAGE STRIDE LENGTH = 3 FEET
STEPS IN A MILE = 5280 FEET
5280 FEET / 3 = 1760 STEPS
317 ms * 1760 STEPS = 558,920 ms

558,920 ms = 9 mins 19 sec

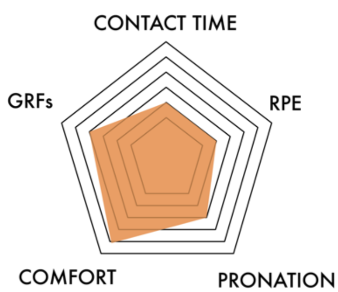
CONTACT TIME: 331 ms

AVERAGE STRIDE LENGTH = 3 FEET
STEPS IN A MILE = 5280 FEET
5280 FEET / 3 = 1760 STEPS
331 ms * 1760 STEPS = 582,160 ms

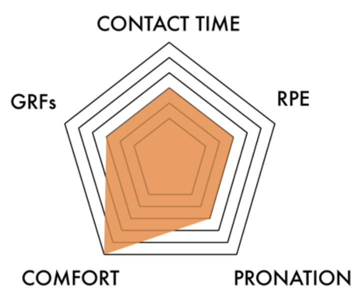
582,160 = 9 mins 42 sec

AT THE SAME EFFORT, THE PERFORMANCE SANDAL PERFORMS 23 SECONDS FASTER PER MILE THAN ALL BASELINE PRODUCTS AVERAGED.

FINAL RESULTS



SPEED SANDAL



RECOVERY SANDAL

ATHLETE INSIGHT

"I'VE NEVER FELT A SHOE THAT DOESN'T DIG INTO THE SAND LIKE THIS."

"MY FEET DIDN'T FEEL CONSTRICTED AT ALL, IT WAS A RELIEF I HADN'T FELT BEFORE."

DREW WHITED
FORMER NCAA D1 DISTANCE RUNNER

THANK YOU
(KOMMOL)