# Stabilizing Shoe Inserts Project

Health: Injury Reduction and Rehabilitation

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Ray Ewry Sports Engineering Center

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## Abstract

Most injuries in jumping sports are to the ankle, accounting for 58% of all basketball injuries and 63% of all volleyball injuries [1]. The majority of these injuries, 77.1%, are to the lateral ligament complex, injuring the anterior talofibular ligament (ATFL) [1]. To combat this, the team at the Ray Ewry Sports Engineering Center developed a prototype using high tensile strength Kevlar fibers in a polyamide 6 matrix to resist the ankle sprain motion that injures the ATFL. These fibers are inserted into a 3D printed thermoplastic polyurethane (TPU) insole which slides into a shoe. In previous testing, the prototype, shown in figure 2, showed the capability to resist the ankle sprain mechanism. This mechanism, called supination which is shown below in figure 1, was simulated disallowing the prototype to slip down the leg, and the prototype displayed a force spike. However, when slip was allowed, the prototype was ineffective. Therefore, the team conducted experiments to control the slip of the prototype down the leg using silicone rubber and compression sleeves. Each sample was pulled vertically down the leg. Ultimately, the team found that the assembly in which the prototype was fixtured on top of a compression sleeve lined with silicone rubber disallowed slip of the sleeve and only slipped due to any improper fixturing of the prototype to sleeve. Therefore, as the slip of the prototype can be controlled, the prototype should be tested under rotation to confirm functionality in supination.

Fig. 1: Ankle Sprain Supination Mechanism, from [2]

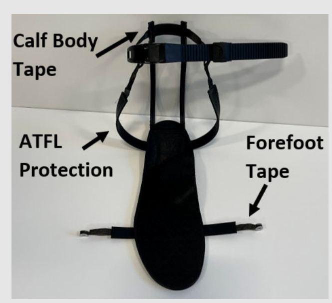


Fig. 2 Insole prototype

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## Project Overview

With ankle injuries being the most common injury in jumping sports, and injury to the anterior talofibular ligament (ATFL) being the most injured component of the ankle [1], the team at the Ray Ewry Sports Engineering Center aimed at supporting this ligament in the ankle supination mechanism. This is the outward and downward rolling of the foot, shown in figure 1, causing an ankle sprain. The team used Kevlar fibers in a polyamide 6 matrix (called “tape”) in a 3D printed thermoplastic polyurethane (TPU) insole to provide resistance to target areas. This resulted in a tape path being run under the foot, perpendicular to the ATFL, and up to meet another tape/TPU ring wrapping around the calf body, as shown in figure 2. This configuration mimics key support straps found in an ankle brace which allows for the calf body muscle group to be used [3]. The prototype was tested in rotation, and only increased the force necessary to turn the model leg in supination if the prototype was forcibly held up with screws, not allowing it to slip down the model leg. Thus, to have the prototype be effective for athletes in supination scenarios, the prototype must stay fixed to the leg and not slip when force is applied. The team explored multiple samples for which this could be controlled and tested them in experiments using a common piece of the prototype, the upper tape ring shown in figure 3, in each sample.

Fig. 3 Upper tape ring used in testing samples

## Project Method and Results

There were 6 prototypes made to test different variations of the upper tape ring (strap). The prototypes included: 1) the strap over the compression sleeve, 2) the strap under the compression sleeve, 3) the strap with a silicone lining over the compression sleeve, 4) the strap with silicone lining under the compression sleeve, 5) the strap alone, and 6) the strap with a silicone lining alone. Each prototype was then tested in two different testing methods. The first test was on a human leg using the luggage scale pull test method as shown in figure 4. The prototype was placed on the human leg, and a luggage scale was attached to the strap. The strap was then pulled until it slipped 2cm down the leg, and the corresponding force at that point was recorded. The second test was carried out the same way as the first test but was instead performed on the metal leg from the rotation test. Again, the prototype was pulled until the strap slid down 2cm, and the force was recorded. The forces recorded could then be compared across prototypes to analyze which variation of prototype was most effective in preventing slip. The prototype that can withstand the greatest amount of force before slipping 2cm is the most effective.

Fig 4. Human testing setup

## Project Method and Results (cont.)

As seen in the graphical results below in figure 5, the testing on the metal model leg resulted in larger forces present to pull the samples down the leg 2cm. Also, the samples with silicone lining required much more force to pull relative to those without silicone. Furthermore, the samples with compression sleeves also performed better than those without. Therefore, the samples with silicone and compression sleeves drastically outperformed the other samples, especially in the human leg testing. Between the samples for which the sleeve was under the strap, the findings from the test were not entirely accurate to the slip observed, as the slip observed was from improper adhering of the strap to the sleeve. The strap only moved due to inadequate sewing of the strap to the sleeve. In fact, the sleeve did not slip, and the testing leg itself moved instead of the sleeve at high forces. Thus, this sample provided the best solution to slip, and the adherence of the strap to the sleeve is critical to preventing the strap from moving. The samples lined with silicone were difficult to take on and off both the model and human legs, and a more efficient way of accomplishing that must be found. One way to fix this is to create smaller length segments of silicone for the compression sleeve to be stretched more effectively. Additionally, different size and pressure compression sleeves should be considered.

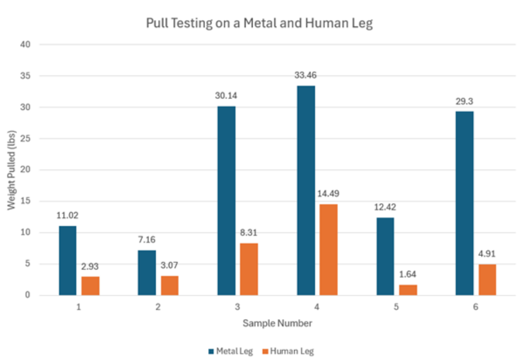


Fig. 5 Force vs angle graph detailing prototype performance under supination

The testing procedure can also be improved. This can be done by fixturing the model and human leg more effectively to allow only the sample sleeves to move. This is only an issue for the silicone sleeve samples, as the applied force caused the leg to shift before any slip occurred. Also, the way we gathered data was slightly subjective. We manually read the force measurement off the luggage scale at the time when it looked like the prototype slipped 2cm. We could possibly use an app that actively measures force as we carry out the test to obtain more objective results. Moving forward, rotation testing should be completed with a silicone-lined sleeve to prevent slipping. This has proven to reduce slip and will allow the prototype to stay in the fixed position, which keeps the tape tight to the leg and allows it to absorb the most force in supination. An image of the tape being pulled tight to the leg in rotation testing is presented in figure 6.

Fig. 6: Tape in tension in rotation testing

## Future Work

- Explore alternate testing methods for prototypes
  - Improve accuracy of force measurements with a software like ForceTest, a force measurement software by Ametek to collect data
  - Floor drop test
- Develop customization system for insert size and tape length
- Explore new sources for more athletic based silicone
- Explore appropriate pressure for compression sleeve

### References

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[2] BoulderCentre for Orthopedics & Spine. (2018, January 3). Anatomy of an ankle sprain. https://www.bouldercentre.com/news/anatomy-ankle-sprain

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# Ray Ewry Sports Engineering Center

## About RESEC

The Ray Ewry Sports Engineering Center (RESEC) is named in honor of a record-setting Olympian and College of Engineering graduate, Ray Ewry. As a joint effort between Purdue College of Engineering and Intercollegiate Athletics, the center reflects Ewry's passion for both sports and engineering and creates research and learning opportunities to athletes and students alike.

## What is Sports Engineering?

Sports Engineering is a multidisciplinary field that uses engineering principles to create solutions to the greatest challenges and opportunities facing sports today. The field utilizes scientific theory, practical application, and technical knowledge to address sports-related challenges through data-driven insights and a results-oriented approach. To contribute to this field RESEC aligns it's investigations with the following priorities

### EXCITEMENT

*Smart Performance & Fan Experience*

How can we use the latest sensors, signal processing, and analytics to improve athlete performance and improve engagement with fans?

### INTEGRITY

*Fairness, Accessibility & Social Integration*

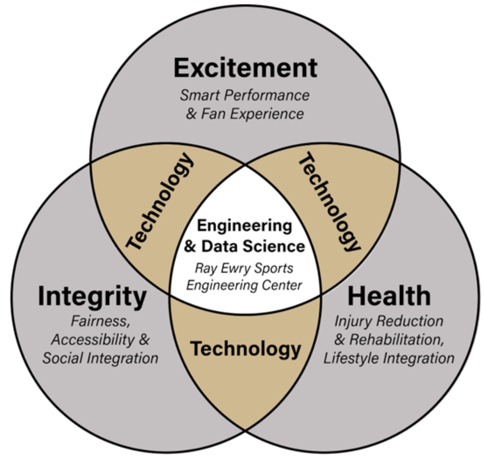
As technology in sports grows, what are the limits of human judgement, and how do we develop technology to ensure a level playing field?

### HEALTH

*Injury Reduction & Rehab, Lifestyle Integration*

What aspects of advanced healthcare and science can be engineered into solutions for sports rehabilitation and performance?

Every sport must balance these priorities to create the best experience for all. RESEC searches for the technology to fill the gaps between each priority and facilitates collaborative research across Purdue through the application of engineering and data science




## Research Technology Platforms

RESEC categorizes industry partners and academic affiliates into the following technology platforms for scaling and implementation to streamline collaboration.

- **Smart Materials for Performance and Safety**
- **Accessible Technology for Societal Integration**
- **Equipment Design for Athlete Feel and Control**
- **Intelligent Prototyping for Rapid Development**
- **Digitalization of Sports Ecosystems**
- **Spectator Experience and Fan Engagement**

When ideas arise from industrial partners or internal faculty affiliates, RESEC facilitates the operations necessary turn opportunities into action.

## Education Offerings

Purdue's academic prowess offers a unique opportunity to engage talented students, staff and faculty members with sports engineering. In addition to research opportunities for undergraduate and graduate students, RESEC is proud to offer the first comprehensive Professional Masters Concentration in Sports Engineering in the United States. With these capabilities, we are equipping the next generation of sports engineers to redefine what's possible.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