Stabilizing Shoe Inserts Project

Health: Injury Reduction and Rehabilitation

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Abstract

With ankle injuries being the most common injury in jumping sports, accounting for 58% of all basketball and 63% of all volleyball injuries [2], a mode of footwear for athletes should be developed to mitigate ankle injury in an ankle sprain mechanism. This project aims to support the ankle ligaments in an ankle sprain, while confining the support mechanism to an insole-sized prototype. 77.1% of ankle injuries are to the lateral ligament complex, indicating a low ankle sprain [3], where the anterior talofibular ligament (ATFL) is the primarily injured ligament. To provide safe and effective support to the ATFL, a counterforce should be applied that inhibits supination and tearing of the ligament. A depiction of the supination mechanism is shown in figure 1.

The thermoplastic polyurethane (TPU) prototype developed in this project uses Kevlar fibers in a polyamide 6 matrix, called tape, in target areas to provide resistance to supination. This tape is used to provide a counterforce to the ATFL by resisting supination through its high tensile strength, mitigating injury of the ligament. This prototype (seen in figure 2) was tested in a rotation testing apparatus in a load frame to observe its behavior under a 60-degree angle, the angle necessary to cause injury [5]. The prototype showed a high resistance to supination via a spike in the force-displacement curve recorded from the load frame as the tape was pulled into tension. This demonstrates the prototype's ability to provide a counterforce at a desired angle of supination.

Fig. 1 Ankle rolling mechanism Source [1]

Fig. 2 Insole prototype

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Project Overview

To combat the frequency of ankle injuries in jumping sports, the team at the Ray Ewry Sports Engineering Center is developing a prototype that protects the most frequently injured ligament of the ankle (the anterior talofibular ligament, or ATFL) in an ankle sprain mechanism. This ankle sprain mechanism, also known as supination, injures the ankle when a 60-degree angle is induced between the bottom of the foot and the ground [5]. The prototype that the team has configured includes three tape (a flat strand of Kevlar fibers in a polyamide 6 matrix) strands. The forefoot tape is located under the foot where the majority of the jumping and landing force is concentrated [4]. The ATFL protection tape path runs from below the ankle upwards, traveling perpendicular to the ATFL. The calf body tape path runs around the leg shank, tying in the ATFL tape to the calf body muscle group. To test this prototype in supination, an aluminum apparatus was configured using SolidWorks 3-D modeling that would bend at the location of the ankle. This then elongated the tape path running over the ATFL and pulled it into tension. This apparatus was designed to be compressed in a load frame while being gripped at the top and the bottom. From this, prototype validation and quantitative results were obtained.

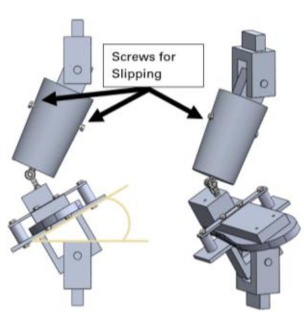

Fig. 3 a and b Testing apparatus with angle of supination shown

Project Methods

Previous iterations of the prototype used carbon fiber in a polyamide 6 matrix tape because of its high tensile strength. The updated prototype uses Kevlar fiber in a polyamide 6 tape because it is flexible to prevent the tape from breaking on bending but also has a high tensile strength. The testing apparatus presented in figure 3 was used in a load frame such that force could be applied to the ATFL tape path of the prototype. This allowed for quantitative measurements of the prototype's ability to resist the supination mechanism of the ankle. To test this, the CAD model testing apparatus was first printed in polylactic acid (PLA) pieces to confirm the dimensions and fit of the parts together assembled with the prototype. After the parts were confirmed to be correct, they were machined from aluminum. The prototype is fastened to this apparatus by strapping around the model shin, which fills the volume where the tape paths run, and by screwing the TPU insole to the model foot. The full assembly in the load frame can be seen in figure 4. The testing apparatus has two screws, labeled in figure 3, on either side of the model shin which hold up the prototype and disallow the upper tape path to slip down the model shin when pulled into tension.

Fig. 4 Prototype in testing apparatus

Project Results and Conclusions

With these screws supporting the prototype and disallowing any slipping, a maximum force case was obtained. This is a result of full tension being obtained as the tape remained straight and in tension. Two other cases for slip are possible: a full slip condition where no screws and minimal friction is present and an intermediate condition where a typical basketball sock is pulled over the model shin to provide friction for the upper tape path to resist slipping. During load frame testing, the prototype showed a sharp force increase when the tape was pulled into tension as desired, as seen in figure 5 at around 86 degrees of supination. This demonstrates the prototype's ability to resist the supination of the ankle, thus protecting the ATFL from injury. However, the prototype provided this resistance at a much larger angle than the desired 60 degrees. This is a result of the path length of the ATFL tape path being too large which can be fixed by multiple methods such as shortening the path length and raising the height of the screws on the apparatus to increase the length necessary for the ATFL tape to travel. The force displacement curve for this experimental trial is shown in figure 5. The trial that produced this curve was run with the no slip condition and conducted at 5 cm/min compression rate.

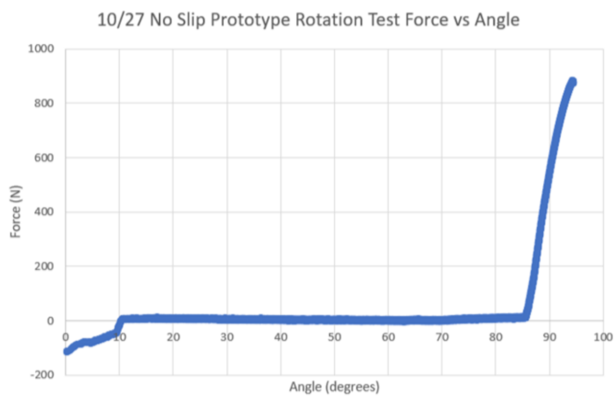

Fig. 5 Force vs angle graph detailing prototype performance under supination

The prototype was unable to obtain results for any experimental run besides the no-slip condition. Therefore, controlling the amount the prototype slips down the athlete's leg is an important design parameter that has a significant effect on the prototype's ability to alleviate force from the ATFL, better protecting the athlete from injury.

Therefore, in the future, multiple methods to control this slip will be tested for functionality. These methods include adding a hook-and-loop fastener to contact the athlete's sock, a wedged sock under the upper tape path, and a contracting loop that tightens around the shin when the tape path elongates.

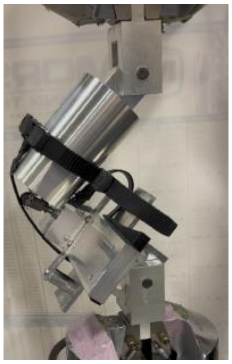

Fig. 6 a and b Prototype slip in full slip (left) and no slip (right) conditions

Future Work

- Create a prototype with shorter ATFL tape path lengths to load force at 60 degrees of supination
- Try multiple methods to reduce slipping of the prototype down the leg shank of the athlete
    - Hook and loop fastener, wedged sock, self-contracting loop
- Use a hook-and-loop fastener instead of rollerblade fastener for ease of use and comfort
- Develop a presentation for the International Sports Engineering Association 2024

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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

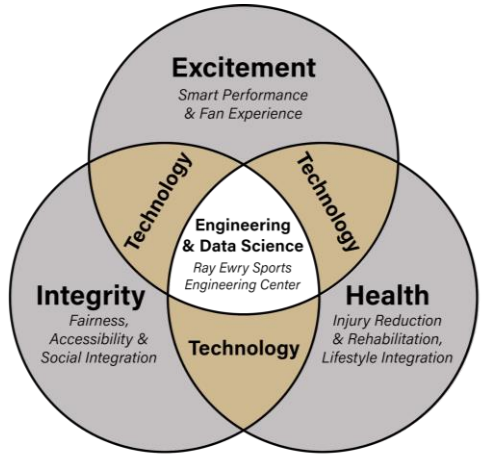
As technology in sports grows, what are the limits of human judgement, and how do we develop technology to ensure a level playing field?

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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