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Increasing Stability in Athlete Footwear for Injury Prevention

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ABSTRACT

Professional basketball athletes frequently suffer injuries to the lower body, and specifically sprained ankles due to player contact. Sprained ankles are the most common type of lower body injury damaging primarily the anterior talofibular ligament (ATFL). This ligament is injured by the rapid outward acceleration of the ankle, causing concentrated stress on the ATFL resulting in a sprain or tear. This occurs when the body weight of the athlete is shifted past the weight bearing leg, frequently because of contact with another athlete.

To combat this, hinged ankle braces use rigid plastic to immobilize the ligament and prevent it from rolling outward. This complete immobilization can result in the force load applied to the athlete to move up the leg shank. The force can then concentrate in the knee or hip, creating a more serious injury. Therefore, there needs to be a counterforce applied to the ankle to lessen the outward acceleration without stiffening the ligament and moving the force load. This counterforce must absorb a portion of the force without immobilizing the ATFL.

Figure 2: Ankle Rolling Mechanism

Figure 1: Hinged ankle brace with rigid plastic

PROJECT OVERVIEW

The ankle contributes to the majority of lower body injuries in athletes. The goal of this project is to provide stability and decrease outward acceleration of the ankle using hard plastic tape (a flat strand of stiff plastic) or tow (plastic materials formed into a circular cross section). The purpose of this material is to absorb the acceleration while still maintaining the force in the lower portion of the leg shank. This will provide an intermediate amount of resistance to injury in the ligament, keeping the injury from becoming more serious in the knee or hip.

The insole prototype encompasses a multitude of the efforts described above. In this prototype, all materials are 3-D printed except the tape strands. A tape strand that is placed under the pad of the foot in the final prototype. This path ran on the inside of the shoe up around the tongue to tie into the laces of the shoe. The purpose of this extension was to transfer the location of the force load to the laces. The tow path beginning in the heel of the insole runs perpendicular to the ATFL to provide support against ankle sprains. This mimics a strap commonly present in hinged ankle braces which supports the ATFL. The final portion tied in the other support structure to the calf body. This portion ran in a circle around the upper portion of the ankle by the calf body. This support mimics the hard plastic of hinged ankle braces on the back of the foot running alongside the Achilles tendon. The initial physical prototype was printed in soft thermoplastic polyurethane (TPU), with polyamide prepreg tape impregnated with carbon fiber in the locations of the tape paths. This will allow for a soft cushioned sole combined with hard plastic to provide rigidity where desired.

Figure 4: Tape Secured Around Bushing

To form the bushings securely, a thin strand of tape was heated around the bushing uniformly. The bushing was clamped steady with a vice, and the tape was warmed with a heating gun. After the tape was wrapped around the bushing, the straight sections were heated to each other, creating a tight loop. Finally, the tape on the insole prototype was trimmed, and the two straight sections were heated together to form one tape path.

Figure 3: TPU Encased Polyamide Tape

PROJECT METHOD AND RESULTS

PREVIOUS DESIGNS

This project is a continuation of a previous shoe design that used shear thickening fluid (STF) in the sole to dampen jump landing sequences but provide stiffness for takeoff. This design was altered to a plastic tow path shoe design to provide more stability in target areas. This method printed a shoe sole of TPU with tow inserts, and the sole was glued together. Due to feasibility issues with production of the whole shoe, this design was discarded as well.

Figure 6: Calf Support with Bushing

PROJECT METHODS AND RESULTS CONT.

To make the prototype, 3-D models were made on a modeling software. The prototype incorporated slots for tape strands incased in TPU to run through and connect to the shoe via bushings. The TPU strands were 3-D printed by printing half of the TPU shell, pausing the print and laying down polyamide tape before finishing the print. The same method was used to create the heel support and shoe sole. The sole was paused three times to lay in the three supporting tape strands. Adhesion was created by 3-D printing material over the tape without glue, and the tapes maintain a strong tensile strength. The tape strands are tightened to the shoe through aluminum bushings. Two bushings connect to the laces at the front of the shoe, and the other four bushings connect around the calf body which can be laced together.

Figure 7: Integration of TPU Prints in the Insole Prototype

ANKLE STABILITY

With the vast majority of basketball and volleyball injuries being ankle related, the main focus of stability for this design is preventing ankle injury. The anterior talofibular ligament (ATFL, located on the outside of the foot) is the most commonly injured as the ankle accelerates outward. Our design provides stability by loading polyamide tape in tension across the foot and calf body to provide stability and hinder ankle acceleration.

Figure 5: Insole Prototype

CONCLUSIONS AND FUTURE WORK

Conclusions

- Printing with multiple materials helps combine the material properties while maintaining a secure connection between them.
- An intermediate amount of force should be applied to the ankle to prevent serious injury.

Future Work

- Test viability of design to decrease ankle acceleration
  - Test stress tape is under or strain it endures
  - Accelerometer tracking ankle
- Test intrinsic properties of the prototype such as tensile strength, outward resistance provided.
- Integrate carbon or glass fiber tow in a TPE matrix

REFERENCES

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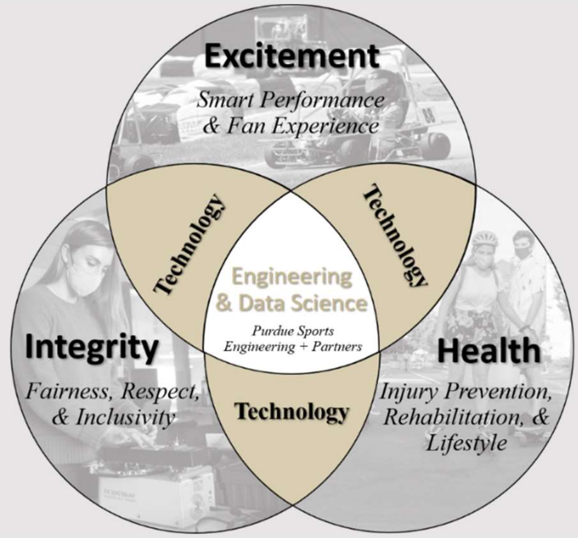
Fig. #6 Prototype

ABOUT RESEC

The Ray Ewry Sports Engineering Center (RESEC) was launched as a joint collaboration between Purdue College of Engineering and Purdue Intercollegiate Athletics, highlighting Purdue's reputation as the Cradle of Quarterbacks and Astronauts.

Sports have the power to unite, to teach, to challenge, and to initiate change, and those are our goals for RESEC. We are driven by our passion for sport and a deep understanding of the influence it has in shaping society. As technology continues to advance, there is enormous room for opportunity to rethink how athletes train, coaches coach, fans engage, and event organizers plan events. We collaborate closely with partners in athletics, industry, academia, and more to create the solutions that will help bring sports into the future, specifically in the three key research areas highlighted below.



Smart Performance & Fan Experience

Injury Reduction & Rehabilitation

Sports Integrity, Fairness, & Societal Integration

WHAT IS SPORTS ENGINEERING?

Sports engineering is a global, fast-paced, and multidisciplinary industry that brings people from different backgrounds, cultures, and experiences together. It is an industry that is heavily influenced by advances in other sectors as well as societal pressures and shifts, making working as a sports engineer very exciting. However, it also means being keenly aware of how these innovations and discoveries can be integrated and applied, especially as digitalization expands and what people – the athletes, fans, coaches, governing bodies – expect from sport evolves.

Engineering and data science are at the center of excitement, health and safety, and the integrity of sport, and by bringing a data-driven, human-centered approach to this industry, we can address the growing need and desire to increase participation and engagement of athletes and fans.

WHO IS RAY EWRY?

A Boilermaker track and field athlete, Ewry (1873-1937) won eight gold medals in three Olympic Games from 1900 to 1908. But his story is relatively unknown: at the age of five he became an orphan, and at seven he contracted polio and was confined to a wheelchair. Doctors had little hope he would be able to walk. Later nicknamed "The Human Frog," Ewry won gold in the standing long and high jumps and standing triple jump. By the end of the 1908 Games, Ewry had set a medal count record that lasted more than 100 years.