Development of Stabilizing Shoe Inserts and Testing Apparatus to Mitigate Ankle Injury in Sports

Evan Grothen[1], Teal Dowd[1], Colin Hansen[1], Jan-Anders Mansson[1]
[1] Ray Ewry Sports Engineering Center (RESEC), Purdue University
1105 Endeavour Drive Suite 400, West Lafayette, IN, 47906, United States of America

Introduction

The ongoing effort to protect athletes in jumping sports centers around the ability to protect the ankle from injury. Ankle injuries are the most frequent injury to basketball and volleyball players, accounting for 58% and 63 % of all injuries respectively [1]. From earlier NCAA studies, it was reported that 77.1 % of ankle sprain injuries are to the lateral ligament complex, which indicates a low ankle sprain [2]. Multiple ankle sprain prevention methods already exist to resist the ankle sprain mechanism such as ankle braces. The weakest and primarily injured ligament of this complex is the anterior talofibular ligament (ATFL). An ankle sprain is induced by the rapid supination of the foot, with a 60-degree angle of supination [3] being sufficient to injure the ATFL and the major component in injuring the ankle [4]. Also, applying a stiff counterforce to the ankle will redirect the force induced to the leg in an ankle sprain up to the knee or hip, resulting in a more serious injury. Therefore, footwear that provides strength with force absorption to the ATFL and disallows a 60-degree angle of supination is ideal in preventing injury to the ATFL. This paper will discuss the fabrication of a tailored prototype that resists ankle supination and a method for prototype validation.

Methods

The team at the Ray Ewry Sports Engineering Center at Purdue University developed an adjustable shoe insole prototype that used high strength continuous carbon fiber composite tape with a polyamide 6 matrix (PA6CF) in target areas to resist extreme supination of the foot. The prototype is constructed by combining PA6CF tapes with a 3D printed thermoplastic polyurethane (TPU) shell for comfort. The tape material is selected for sufficient adhesion to the extruded TPU to eliminate the need for glue in the prototype.

The prototype has three PA6CF tape inserts. The forefoot tape contains PA6CF tape wrapped around a ridged bushing which terminates at the laces on top of the shoe. As seen in Figure 1, the laces of the shoe run through the bushings on either end of the tape and are fastened to the shoe by tightening the laces. The reinforcement tape is located along the path of the primary jumping and landing forces to redirect some of this force away from the pad of the foot [5].

Figure 1a and 1b: Prototype with stability inserts labeled and when worn

The ATFL protection tape path runs perpendicular to the ATFL to provide resistance to the ligament. This tape mimics a strap on the patented ankle brace by Igmundarson et al. [6]. The tape, like the strap of the patented brace, terminates at the calf body to activate another muscle group for additional force dissipation. The calf body tape, indicated in Figure

Corresponding author email: jmansson@purdue.edu

1, wraps around the leg shank to activate that muscle group and secure the ATFL tape path to the leg. This tape path is terminated with an adjustable buckle fastener.

Description

Two testing setups were conducted to quantify the support the prototype provides and optimize the strength of the PA6CF tape strands in the insole. Tensile testing of PA6CF tape wrapped around bushings of varying overlap lengths was performed to determine the overlap length that provides the prototype with the highest tensile strength. Samples with 3 centimeters of straight section overlap gave the highest strength at the first major breakage and maximum tensile strength. Thus, a 3-centimeter overlap length was used for overlaps of PA6CF connections for the remainder of the study.

Also, a model was tested under a 60-degree rotation in the specially designed test apparatus shown in Figure 2 to examine the force absorption of the prototype in the event of an ankle sprain to which a model leg was constructed with an ankle joint correct to human anatomy. Furthermore, a model foot and leg shank were adapted to fill the volume of the prototype. The natural bending resistance of the model apparatus served as a control to the trials run with the prototype attached. An angle was induced at the hinge in the location of the ankle interface by the compression of the load frame. This was continued until the interface was at an angle where the prototype was in tension, for which the force showed an sharp increase demonstrating the ability to provide a large counterforce under extreme rotation.

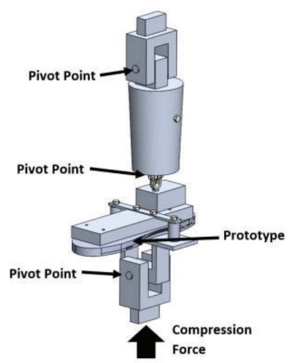

Figure 2: Computer Aided Design of prototype testing apparatus

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Corresponding author email: jmansson@purdue.edu