AIRfeet® and Its Effects on Plantar Pressure

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ABSTRACT

AIRfeet® is a new development in orthotic footwear that uses dynamic fluid channeling technology, designed to give its wearer several noted benefits such as decreased shock absorption, improved balance, and increased foot speed and strength. Also, AIRfeet® was created to enhance the pressure diminishing capabilities of off-the-shelf closed-toed footwear through the use of fluid. The novel orthotic uses fluid to distribute plantar pressure across the plantar surface of the foot. Since this technology is the first of its kind, a methodology was developed to analyze the mechanics of the fluid channeling technology and quantify the relationship observed between the use of AIRfeet® and plantar pressure. The results from this unique methodology noted that AIRfeet® did not consistently reduce plantar pressure across the plantar surface and can provide additional benefits than those initially noted.

Background

Plantar pressure is the force produced on the plantar surface when it comes in contact with another surface such as a hardwood floor or concrete. Footwear is intended to provide a protective housing for the foot, accommodate foot structure, facilitate foot function and reduce plantar pressures.[1,2,3] In some instances, where high impact cyclic loading is prevalent, such as in diabetic populations, it is essential to reduce plantar pressure to limit injury and optimize foot function.

The ability of a material or surface to reduce impact encountered along the plantar surface or decrease plantar pressure is known as shock absorption.

Shock absorption in footwear is accomplished through the strategic application of material properties and optimization of footwear geometry. Shock absorption is important in footwear as humans experience forces one and a half to three times their body weight during normal daily activities.[4,5]

Current solutions that aid in reducing plantar pressure and absorb shock are expensive and are dependent upon shoe housing geometry and materials. A cost-effective solution is needed to address the challenge of reducing plantar pressure and enhancing shock absorption properties of existing footwear housing architecture.

AIRfeet®'s Dynamic Technology

AIRfeet® is a fluid-filled orthotic insert that rapidly diffuses fluid, using dynamic fluid channeling technology, from areas of high pressure to low pressure during dynamic loading. The innovatively designed channels span from the proximal sides of the heel to the metatarsophalangeal joint of the toes, in other words, the front edge of the ball of the foot allowing the fluid to strategically flow throughout AIRfeet® when catalyzed. A detailed graphic of the AIRfeet® and its fluid channeling technology can be see in the appendix.

Walking Trials with AIRfeet®

Currently, there is no standard method developed to measure the shock absorption of a fluid-filled orthotic due to its behavior under dynamic loading. Normally, shock absorption characteristics are defined using ASTM Standard 1976-13 *Standard Test Method for Impact Attenuation of an Athletic Shoes,* a test method that drops a gravity-driven missile repeatedly on a test specimen and examines the shock dissipation over a set time limit. This isn't applicable for AIRfeet® as the fluid relies on a restoring force to return the fluid to its original position (compared to specimen used in the ASTM test standard which recovers without a restoring force). Therefore a test method was developed to measure the reduction of peak plantar pressure during treadmill walking while wearing AIRfeet®

A participant was asked to walk on a treadmill for forty-five seconds under three different conditions, presented in random order, at a speed they perceived was comfortable. The three conditions were as follows: instrumented insoles only, instrumented insoles with non-fluid filled AIRfeet® and instrumented insoles with fluid-filled AIRfeet®. Anti-skid aqua socks were used to hold the instrumented insoles and AIRfeet® in contact with the participant's plantar surface during walking trials.

Figure 1: Researcher walking on treadmill with instrumented insoles system tethered at waist.

Measurement of Plantar Pressure

Pressure measurements were taken using a pedar® system which is an instrumented insole measurement system consisting of 99 individual pressure sensors that span the plantar surface. The pedar® system was divided into three key regions: the toes, the forefoot and the rearfoot as noted in Figure 3. Individual Step Data was aggregated from each insole condition and region. A statistical analysis was used to compare mean peak plantar pressure of each region for each insole condition .

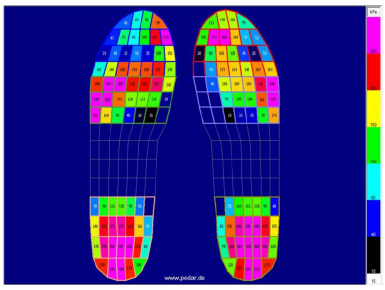

Figure 2: A screen capture of the pedar® system insole capturing plantar pressure data. Pressures range from 0 kPa (black) to 300kPa (magenta)

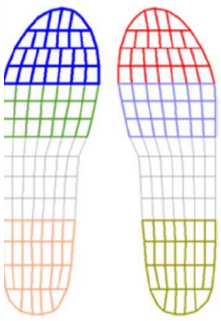

Figure 3 : A screen capture of the pedar® system divided into three regions for each foot: toe, forefoot, and rear foot..

AIRfeet®'s Performance During Walking Trials

Data collected from the walking trials suggest that AIRfeet® does not uniformly reduce peak plantar pressure or shock across the plantar surface. The fluid-filled AIRfeet®, noted by the light olive bar in Figure 4, showed the highest peak plantar pressures (~457 kPa) in the rear foot (RRF) region and lowest peak plantar pressures (~187 kPa) in the toe region (RToes). This non uniformity can be attributed to AIRfeet® inconsistent fluid flow. The fluid flow within AIRfeet® was turbulent in the forefoot region. Also, there was very little fluid flow observed within the two smaller outside channels and near the front edge of the forefoot region, causing an inefficient distribution of fluid throughout AIRfeet®.

The general contact area of AIRfeet® with the plantar surface may also be a cause of the five percent higher peak plantar pressures noted in the rear foot(RRF) region and the seven percent increase of peak plantar pressures in the forefoot region (RFF) during walking trials. Since the dynamic fluid channeling within the AIRfeet® did not extend to the front edge of the toes, this may have caused majority of the plantar pressures to be loaded onto the forefoot and rear foot regions of the novel orthotic.

Conversely, an upward trend was observed in the participant's preferred walking speed. There was an increase in the preferred walking speed while the participant wore AIRfeet®. This observation addressed the additional claim of AIRfeet® ability to facilitate an increase in walking speed. Future studies will need to be performed to explore this claim further.

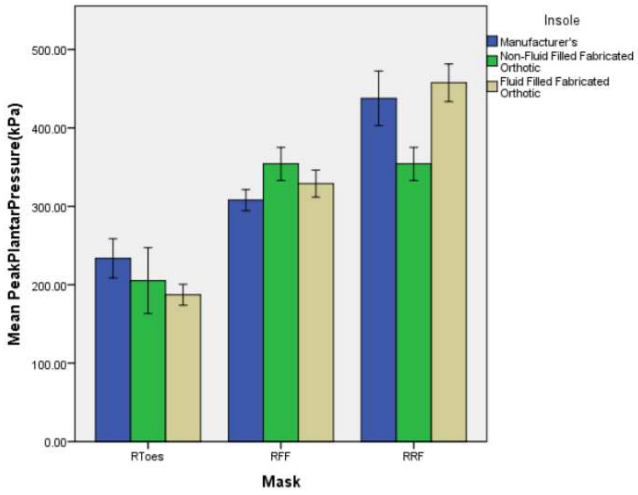

Figure 4:-The mean(+/- 2 SD) peak pressure of right foot in each mask as a function of the insole condition.

Conclusions

AIRfeet® aides in the reduction of peak plantar pressures within the toe region while there were no notable reductions peak plantar pressures within the rear foot and forefoot regions. With the decrease of peak plantar pressures in the toe region, AIRfeet® exhibits potential benefits for the diabetic population prone to ulceration on the toes and individuals with Hallux Rigidus. Since one participant was selected to eliminate anatomical differences in foot structure and walking kinematics, it may be of interest to conduct similar tests to determine how AIRfeet® performance varies with anatomical differences. It would also be beneficial to observe plantar pressures over a more extended time period, such as the course of days or week during normal walking activities, instead of treadmill walking.

Overall, this research suggests that with potential variations of the current fluid channeling technology, such as optimized channel geometry and fluid characteristics, AIRfeet® with dynamic fluid channeling technology can become a universal and inexpensive solution to the reduction of peak plantar pressures for individuals wanting to limit injury and maximize comfort.

References

1. Barton, C. J., Bonanno, D., & Menz, H. B. (2009). Development and evaluation of a tool for the assessment of footwear characteristics. Journal of Foot and Ankle Research, 2, 10. https://doi.org/10.1186/1757-1146-2-10
2. Brodsky, J. W., Pollo, F. E., Cheleuitte, D., & Baum, B. S. (2007). Physical Properties, Durability, and Energy-Dissipation Function of Dual-Density Orthotic Materials Used in Insoles for Diabetic Patients. Foot & Ankle International, 28(8), 880–889. https://doi.org/10.3113/FAI.2007.0880
3. Menant, J., Steele, J., Menz, H., Munro, B., & Lord, S. (2008). Optimizing footwear for older people at risk of falls. Journal Of Rehabilitation Research And Development, 45(8), 1167–1181. https://doi.org/10.1682/JRRD.2007.10.01
4. Schwanitz, S., Möser, S., & Odenwald, S. (2010). Comparison of test methods to quantify shock attenuating properties of athletic footwear. Procedia Engineering, 2(2), 2805– 2810. https://doi.org/10.1016/j.proeng.2010.04.070
5. Swigart, J., Erdman, A. G., & Cain, P. (1993). AN ENERGY-BASED METHOD FOR TESTING CUSHIONING DURABILITY OF RUNNING SHOES. Journal Of Applied Biomechanics, 9(1), 27–46. https://doi.org/10.1123/jab.9.1.27

Appendix

Detailed drawing of the AIRfeet®and its dynamic fluid channeling technology