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COLLEGE OF PODIATRIC MEDICINE AND SURGERY

Teno-Suspension Brace Reduces Pronation Related Loads

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Introduction

Most foot orthoses work by applying an external pressure or force against the foot during weight bearing. These devices are designed to use the physical properties of materials such as plastics and foam to manipulate the external force vector and pressure distribution by positioning the orthosis between the source of the load and the foot. This limits the amount of force available for positional correction to pressures below the level of soft tissue damage.[1] Additionally this type of device is only effective during the contact phase of the gait cycle. (Figure 1)

The Concept

Recent innovations in brace technology have produced braces that wrap the joint segment and have internal load components. [2,3] This opens up the possibility of applying continuous loads on the foot using suspension straps positioned near the surface of the anatomical segment. These suspension straps can be positioned to produce a force vector in any direction or magnitude and therefore can replicate the suspension function of soft tissue such as tendons. (Figure 2) The suspension straps produce a continuous positional force vector applied to a joint segment that can resist changes in the corrected joint position. This type of device works during contact and swing phase of the gait cycle. When there is no external load present during the swing phase the internal forces of the suspension strap holds the joint segment in the desired position. When the foot comes into contact with the ground, the external ground reaction force vector slowly counteracts the internal load of the suspension strap thereby allowing for resisted or controlled motion of the joint segment. This concept has the potential to be applied to the treatment of pronation related pathology such as plantar fasciitis, posterior tibial tendon dysfunction, or even diabetic ulcers.

Figure 1. Standard orthosis applies external force inferiorly based on the contour of the device.

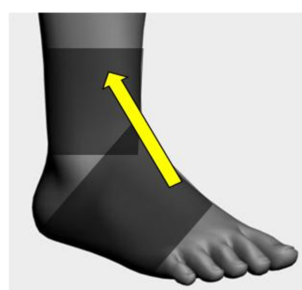

Figure 2. Suspension straps close to the skin act more like internal forces and can be positioned to replicate the vector pull of a tendon.

Purpose and Hypothesis

The purpose of this work was to compare the dynamic function of a teno-suspension brace to a traditional load bearing device covering a similar area. We hypothesize that the teno-suspension style foot and ankle brace will produce equal or better measured outcomes related to foot pronation than a traditional foot and ankle orthosis.

Methods

Ten subjects with no history of foot disorders were recruited to participate. (5Male/5Female, Ave. Age 38(SD±11) years). Each were randomized and fitted with either a BioSkin TriLok Brace or a hinged "Richie" style super malleolar brace on the right foot followed by the left foot. The process was then reversed so each subject wore both braces on both feet in a randomized order for a total of 20 limbs tested in each condition. Subjects walked down a walkway with computerized in-shoe interface pressure mapping devices placed between their foot and the brace. (Tekscan, South Boston MA) Ten steps were recorded for each subject in each of the above conditions. Pressure, force, impulse and medial to lateral load distributions were measured or calculated. Where appropriate data was normalized to body weight for inter-subject comparisons. Center of Pressure Index was calculated as previously reported.[4] Outcomes measures were assessed using SPSS software with independent samples t-test used to compare groups. A multiple regression analysis was also run to determine if group differences remained after adjusting for age, gender, and BMI. A significance level was established at $p \leq 0.05$ *a priori*. Pearson's correlation was used to evaluate any associations between right and left foot data collection. Intraclass correlation coefficients (ICC) were determined for the COP index as a measure of intra-observer agreement between readings carried out at separate time periods.

Suspension Modification

It is important to point out the original design of the TriLok brace was for lateral ankle instability. We altered the placement of the suspension strap so as to replicate the vector pull of the posterior tibial tendon. We started with the foot in a maximally supinated position with the Velcro end of the suspension strap anchored to the dorsum of the navicular. The foot was wrapped once to provide greater leverage with the end of the strap proceeding along the course of the posterior tibial tendon ending posterior to the medial malleolus. (Figure 3)

Figure 3A. Standard "Richie" style brace. 3B. Placement of suspension strap at navicular and ending at medial malleolus (Fig 3C.) Figure 3D shows final configuration of teno-suspension brace.

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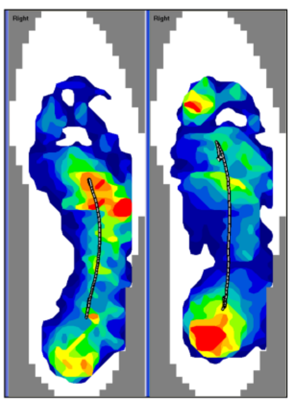
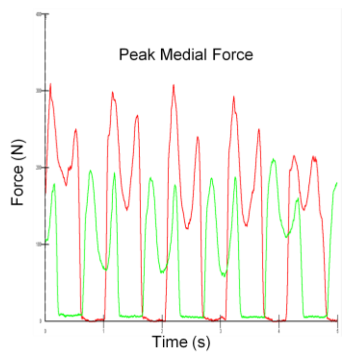
Results

The medial load across the foot was significantly decreased with the teno-suspension brace having a lower average peak force and impulse compared to the standard brace. (Figure 4, Graph 1,2) The medial to lateral load distribution as calculated by the center of pressure index (COPi) showed the teno-suspension brace was better at offloading the dynamic medial foot than the standard brace. -3.5(±3.7) versus 1.08 (±4.4). ($p<0.001$) After adjusting for gender, age, and BMI, the differences between the groups remained significant (β = -3.36, $p < 0.001$). (Figure 5, Graph 3) There was no statistical relationships between right and left data sets nor between time variables. The load under the hallux, heel and lateral column was the most dominant feature of the TriLok brace with the load clearly shifted off the heel and hallux to the lateral forefoot.(Graph 4)





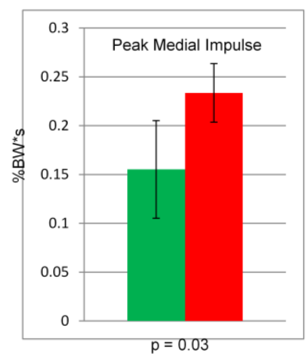
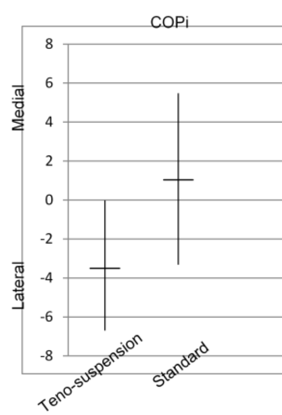
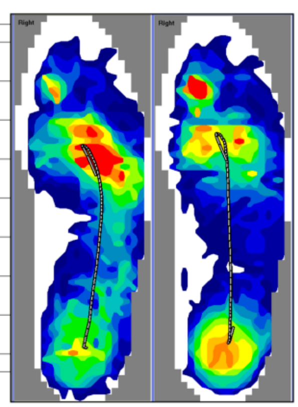
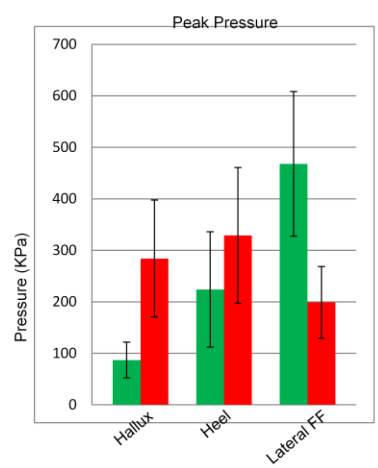


Figure 4. Averaged Peak Pressure Map of a subject with Teno-Suspension on left and standard brace on right
Graph 1. Medial force graph of same subject with teno-suspension brace in green and standard brace in red.
Graph 2. Average medial impulse of all subjects with teno-suspension brace in green and standard brace in red .







Graph 3. Center of Pressure index showing a more lateral load with the teno-suspension device.
Figure 5. The teno-suspension device on the left has a more lateral center of pressure trace compared to the standard brace on the right.
Graph 4. Peak pressure of areas with significant differences. Teno-suspension device is in green and standard brace is in red.

Conclusion

For most subjects the standard "Richie" style brace did a good job at offloading the medial column. One area the standard brace did not offload well was the hallux as compared to the significant reduction seen with the teno-suspension device. On all subjects the teno-suspension brace had significantly lower heel loads but higher lateral column loads. This may be due to the supinated position prior to suspension strap application. However we feel this demonstrates the ability of the teno-suspension brace to significantly alter the loads across the foot. The obvious benefit of the teno-suspension devices are the endless possibilities of placement of the suspension straps thereby changing the direction and magnitude of the force vector. The strap placement for this research was designed to replicate the pull of the posterior tibial tendon but could easily be reversed for lateral ankle stability.

All of the subjects related a feeling of their foot being supinated while wearing the TriLok brace. Although not reported here, during the swing phase of gait there was a noticeable re-supination of the foot after toe off. While sitting the subjects also reported they could pronate against resistance of the internal suspension straps. This opens up the possibility of an added use for such devices for rehabilitative resistance exercises. These data show teno-suspension braces can significantly alter the loads across the foot during gait. Given the open architecture of the suspension strap placement, this type of device could be beneficial in pathology related to instability such as plantar fasciitis, tendonopathies, sprains and even diabetic ulcerations.

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Learning Objectives

1. **Understand how the principle of teno-suspension devices work.**
2. **Understand how this new category of braces can be used to treat pathology related to foot instability.**
3. **Be able to apply this type of modality to the appropriate patient population in your clinical practice..**

Acknowledgements

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