Biomechanical Predictors of Effective Orthotic Therapy for Painful Pes Cavus

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SUMMARY

People who have extremely high-arched feet or pes cavus often suffer from substantial foot pain. Custom-made foot orthoses (CFO) have been shown to be an effective treatment option, but their specificity is unclear. This study sought to identify variables associated with pain relief after CFO intervention. Demographic, physical characteristics and plantar pressure data from a randomized controlled trial of 154 participants with painful pes cavus were retrospectively re-analyzed at baseline and three month post CFO intervention. The participants were randomized to a treatment group given CFO or a control group given sham orthoses. No relationship between change in pressure magnitude and change in symptoms was found in either group. While redistribution of plantar pressure, measured with the Dynamic Plantar Loading Index, had a significant effect on pain relief ($p=0.03$). Our final model predicted 73% of the variance in pain relief from custom foot orthoses and consisted of initial pain level, BMI, foot alignment, and changes in both Dynamic Plantar Loading Index and pressure-time integral. Results indicate that a primary function of effective orthotic therapy is redistribution of abnormal plantar pressures. This study provides the mechanism by which custom-made foot orthoses reduced pain and disability in patients with painful pes cavus. The proposed model may assist in better designing and assessing orthotic therapy for pain relief in patients with a variety of painful foot disorders.

INTRODUCTION

It has been estimated that 60% of people with extremely high arched feet, or pes cavus will experience foot pain, such as metatarsalgia, sesamoiditis and plantar heel pain, all of which are thought to be the result of high, localized plantar pressures [1]. Management of the painful cavus foot has, therefore, been directed toward the reduction of pressure through the application of shock absorbent foot orthoses. Custom-made foot orthoses have been shown to be an effective treatment option [2]. However the mechanism by which they produce an effect is not well understood.

We previously reported a randomized controlled clinical trial into the efficacy of orthoses for painful pes cavus [3,4]. Subsequently, however, we found no correlation between change in pressure and change in pain with the use of custom-made foot orthoses. [5]

Recently, a new method to evaluate changes in dynamic plantar loading have been developed [6,7]. The Dynamic Plantar Loading Index is a method for investigating the redistribution of plantar pressures. The method is based on the probability distribution of peak pressure time series and is quantified using the Regression Factor [6]. The Dynamic Plantar Loading Index is a dynamic plantar loading measure estimated from fitting a person's plantar pressure probability distribution to a Gaussian distribution [6]. In other words it is a direct measure of what has been thought to be an important mechanism of how custom-made foot orthoses work: by redistributing plantar pressures. The Plantar Loading Index is expected to range from - 1 to + 1 and as the value increases positively so does the similarity between the actual and modeled pressure probability distributions [7]. Healthy participants have demonstrated a loading index of 0.46 while patients with major foot deformity like chronic Charcot foot have a negative value.[7] Preliminary testing demonstrated this measure to be independent of gait speed, an important confounding parameter for plantar pressure time-series profile [6,7].

The aim of this study was to model the contribution of the Dynamic Plantar Loading Index with other possible predictors of cavus foot pain reduction with the use of custom-made -foot orthoses

METHODS

Demographic, physical characteristics, musculoskeletal exam, and Pedar[®] in-shoe plantar pressure data from a randomized controlled trial of 154 participants with painful pes cavus were retrospectively re-analyzed at baseline and three month post orthoses intervention [3]. The participants were randomized to a treatment group prescribed custom-made foot orthoses or a control group given sham orthoses.

Foot pain was measured by the well-validated self-reported Foot Health Status Questionnaire (FHSQ) [8] at baseline and after 3 months. The FHSQ is an accurate and reliable measure of foot-specific, health-related, quality-of-life scoring from 0 (worst score) to 100 points. The FHSQ also

assesses footwear suitability and self-perception of general foot health. Scores of 85 and above on any item are considered to fall within asymptomatic ranges [8]. The change in pain score between baseline and 3 months was considered the primary outcome of this study.

In our previous study[6], we demonstrated that cavus foot deformity significantly reduces the Dynamic Plantar Loading Index on average by 41%, increases the magnitude of second peak pressure by 51%, and leads the second peak location by 5.8% compared to healthy foot posture. Thus changes in these three parameters together with changes in pressure time integral (PTI) and maximum magnitude of peak pressure were considered as plantar pressure parameters for predicting pain relief after three months of wearing foot orthoses.

A multivariable general linear model (MANCOVA) was used for between group comparison by controlling the effect of participants' demographics (age, BMI, gender) and participants' foot biomechanics [Foot Posture Index (FPI), Dynamic Plantar Loading Index, peak pressure, PTI, and the magnitude of 2nd peak pressure and the relative location of 2nd peak pressure as a percentage of the stance phase]. In addition, ANCOVA was used for between group comparisons with adjustment by age. A multiple linear regression model (backward) was used to assess significant predictors to pain relief. The type of foot orthoses (Custom foot orthoses=1 and Sham=0) was inserted as the selection variable for the model and the custom orthoses group was selected for the final fitting.

RESULTS AND DISCUSSION
No significant difference was observed between groups for foot pain score at baseline (p=0.1). Although, foot pain scores improved after three months follow-up for both groups, the improvement of foot pain was, on average, 55% higher in the active group compared to the control group (p=0.005, mean difference=11.1, 95%CI=(3.3,19.0)).
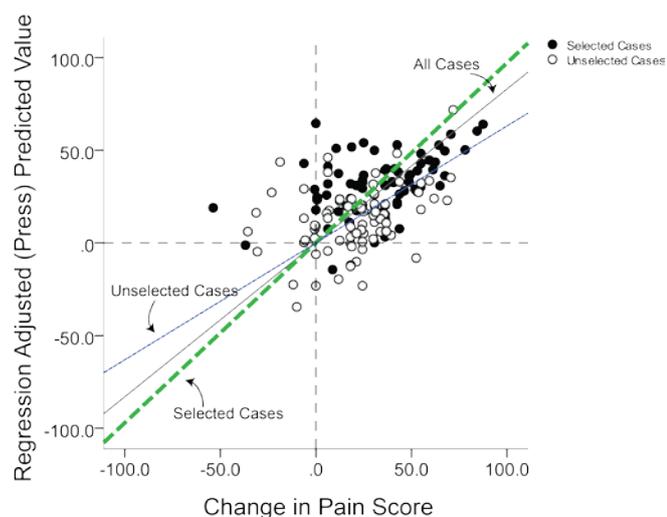
Figure 1: The model output for prediction of foot pain reduction with custom foot orthoses.

No relationship between change in pressure magnitude and change in symptoms was found in either group. While redistribution of plantar pressure, measured with the Dynamic Plantar Loading Index, had a significant effect on pain relief (p=0.03).

We identified both demographic and biomechanical mediators of pain-relief afforded with custom foot orthoses. Our final model described 73% (R^2, Figure 1) of the variance in pain relief with custom foot orthoses and consisted of higher initial pain level, higher BMI, cavoid foot alignment as measured by FPI, and changes in both the Dynamic Plantar Loading Index (e.g. increased towards healthy subjects' value) and decreased PTI. As far as we are aware, we are the first group to describe as much variance in pain relief with custom-made foot orthoses.

There are limitations to our study. This is a secondary analysis of a randomized clinical trial. While the trial was not initially designed or powered to detect these *post-hoc* findings, the design offers strengths over previously underpowered studies investigating the mechanism of custom foot orthoses [5].

CONCLUSIONS
In this study we have identified a range of demographic and biomechanical predictors of pain-relief with the use of custom foot orthoses in people with painful cavus foot deformity. Our final model described 73% (R^2) of the variance in pain relief from custom foot orthoses and consisted of initial pain level, BMI, foot alignment, and changes in both the Dynamic Plantar Loading Index and PTI. Our findings add to the growing body of literature providing mechanistic support for the effect of custom orthoses for a variety of painful foot conditions.

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