Foot Orthotics Reduce The Navicular Drop - A Novel Method Allowing For In-Shoe Measurement

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My name is Birgitte Christensen, I am a physiotherapist and currently studying a master in Clinical Science and Technology at Aalborg University, an during my master one project we have been working on is this novel method allowing for in-shoe measurement of Navicular Drop.
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The longitudinal medial arch is essential for energy absorption (Willems et al 2006).

A lowering of the arch is associated with pronation.

The amount of pronation can be quantified by measuring the Navicular Drop (ND) (Brody 1982; Magee 2008)

- Requires the subject to be in bare feet

The feet's ability to absorb energy are essential for the strain on the body during walking and running and an element essential for this energy absorption is the longitudinal medial arch. The mobility of the arch determinates the amount of pronation and a lowering of the arch is associated with pronation (2).

The amount of pronation can be quantified by measuring the Navicular Drop (ND) (12,13). In the literature the ND is often used to quantify the amount of pronation. But the navicular drop test requires the subjects to be in bare feet.

Malalignments can affect the energy absorption, and especially an increased amount of pronation is associated with load-related injuries (Willems TM, De Clercq D, Delbaere K, Vanderstraeten G, De Cock A, Witvrouw E. A prospective study of gait related risk factors for exercise-related lower leg pain. 2006(23):91.)
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<td>An increased amount of pronation increases the risk of overuse injuries in shin and knee (Willems et al. 2006; Boling et al. 2009)</td>
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![Diagram showing a person walking and the movement of the foot]

Even though pronation is essential for energy absorption, an increased amount of pronation increases the risk of developing over-use injuries in shin and knee.

In this animation you can see how the medial longitudinal arch is lowered during walking.
### Introduction

It has been hypothesized that foot orthotics can limit the amount of pronation (Baxter et al. 2011). Orthotics has been found to prevent overuse injuries, however the mechanisms of effect are unknown (Franklyn-Miller 2010). To date it has not been possible to measure ND when subjects are wearing shoes.

Therefore in this study a novel method, a strain-sensor, to measure in-shoe ND was used, and the aim was to investigate:

1) The validity and reliability of the strain-sensor and
2) If foot orthotics reduced the ND during walking measured with the strain-sensor.

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It has been hypothesized that foot orthotics can limit the amount of pronation and thereby reduce the risk of developing overuse injuries.

Franklyn-Miller et al. demonstrated a positive effect of using orthotics to prevent overuse injuries with an absolute risk reduction of 0.49 when subjects were using orthotics (foot orthoses in the prevention of injury in initial military training). Therefore orthotics is commonly used in the treatment of some overuse injuries, however the mechanisms of the effect of using orthotics are unknown (ibid). A possible explanation of the effect of orthotics is a reduced ND (and thereby pronation) provided by the orthotics, however to date it has not been possible to measure the navicular drop (ND) when subjects are wearing shoes.

Therefore in this study a novel method, a strain-sensor to measure in-shoe navicular drop was used, and the aim of this study was to investigate:
### Methods

The strain sensor:
- Thin, flexible and robust capacitative sensor
- Measures electrical capacitance
- Recordings in custom-made software program Datalogger (Kappel 2012)

Placed between two points
- 20 mm posterior to malleolis medialis
- 20 mm posterior and 20 mm distal to tuberositas naviculare

The strain sensor is thin, flexible and robust capacitive sensor allowing for in-shoe measurements. The sensor is strainable in one direction and measures the electrical capacitance. The sensor is placed between two points and is secured with tape in the distal end and around the ankle with a velcro band. With this attachment, the sensor will be stretch when the longitudinal medial arch is lowered.
Here we have the previous animation with the movement of the medial longitudinal arch, and in this frame you can see how the strainsensor measures the ND during standing or walking.
Validity was measured in two ways

1. Technical validation comparing the degree of stretch from a calibration slade with the stretch measured from the strain sensor (electrical capacitance).
   - Results calculated with a linear fitting and coefficient of determination
   - $R^2 = 0.999$ (Kappel 2012)

2. Comparing ND measured with the strain sensor and ND measured ad modum Brody (static)
   - $n = 24$
   - Difference between the height of tuberositas naviculare with talus in a neutral position and when subjects were standing in their normal relaxed position (Brody 1982)
   - The difference measured with the strain sensor
   - Linear Regression Model performed in SPSS

And the statistical analysis was a linear regression model
Reliability

- n = 27
- Subjects walked two times on a treadmill with one day between
- Intra- and interrater reliability was investigated
- Subjects walked 6 minutes on the treadmill followed by 1.5 minutes of recording (Matsas et al. 2000)
- Results based on 10 consecutive steps identified after 30 seconds of recording in a custom-made program (DataAnalyzer)
- Intraclass Correlation Coefficient in SPSS 20.0

Subjects walked six minutes on the treadmill followed by 1.5 minutes of recording: The six minutes walking before the recording was made, was based on the result from Matsas et al, suggesting that no difference in kinematics is seen between treadmill and overground walking after a period of walking in six minutes.

The results was calculated based on 10 consecutive steps which was identified after 30 seconds of recording.

And the statistical analysis was intraclass correlation coefficient.
Introduction

Foot orthotics (Formthotics)

- Full length, dual-density prefabricated Formthotic™
- n = 24
- Subjects walked 6 minutes on a treadmill with and without foot orthotics in a randomized order followed by 1.5 minutes of recording
- Results based on 10 consecutive steps identified after 30 seconds of recording in a custom-made software program (DataAnalyzer)
- Paired t-test in SPSS 20.0

The results was like in the reliability studie calculated based on 10 consecutive steps, which was identified after the first 30 seconds of recording.

A student paired t-test was performed to see whether or not the orthotics reduced the navicular drop.
Validity

- Linear correlation between ND measured with the strain sensor and ND ad modum Brody (p<0.001)
- R=0.745 (p<0.001)
Introduction

Methods

Reliability

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<tr>
<td>Intrarater, rater 1</td>
<td>0.77</td>
</tr>
<tr>
<td>Intrarater, rater 2</td>
<td>0.78</td>
</tr>
<tr>
<td>Interrater, day 1</td>
<td>0.84</td>
</tr>
<tr>
<td>Interrater, day 2</td>
<td>0.76</td>
</tr>
<tr>
<td>Interrater</td>
<td>0.80</td>
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Results

Foot orthotics

- A reduction in ND when wearing orthotics ($p=0.015$)
- On average, orthotics reduced the ND by 0.4 mm (95% CI: 0.1-0.7 mm, $p=0.02$) corresponding to 19.0% of the average ND without orthotics

The ICC values indicates that the strain sensor is reliable both for intrarater and interrater
The strain sensor is
• Valid compared with ND measured ad modum Brody
• Reliable
• Capable of measuring a reduction in ND when subjects were wearing shoes

The potential of the strain sensor
• Measure movements of the midfoot when subjects are wearing shoes
• Simple and not time consuming which makes it applicable in clinical settings

Capable of measuring of a reduction in ND when subjects were wearing shoes: This may explain why some studies find that orthotics decrease the risk of overuse injuries.

How can we validate the strain sensor when subjects are wearing shoes in dynamic measurements? We do not have methods to measure ND in shoe, so what method can we compare the strain sensor to, and how much do we know about the alterations in ND when subjects are walking bare footed compared with shoes? And is it necessary – we see that the strain sensor can measure a reduction in the ND when subjects are walking with orthotics, is that enough?
Acknowledgement

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This study was a teameffort, so I would like to thank the rest of the research team and the fundings for making it possible.