SAGITTAL PLANE MOTION OF THE MEDIAL LONGITUDINAL ARCH IS UNCHANGED IN PLANTAR FASCIITIS

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INTRODUCTION

Plantar fasciitis is characterised by pain involving the medial calcaneal tubercle that is exacerbated after periods of non-weightbearing (Tontas & Fornasier, 1996). Although the pathogenesis is poorly understood, lower limb biomechanics or foot types that result in a lowered and elongated medial longitudinal arch have been widely cited as causal factors in the development of the condition (Cornwall & McPoil, 1999; Taunton et al., 1982). There is little experimental evidence, however, linking arch motion to the pathogenesis of heel pain. While Rano et al. (2001), in a radiographic study, reported that 27 of their 59 (46%) plantar heel pain patients had an abnormal arch structure, the arch profile of patients did not differ significantly from control subjects. Similarly, Warren (1984) found no difference in the arch shape of patients with and without plantar heel pain when arch height was measured during stance. The authors concluded that static, clinical measures of arch height were poor predictors of plantar fasciitis in runners.

In contrast, Prichasuk and Subhadrabandhu (1994) observed a significantly lower calcaneal pitch in a radiographic study of 82 heel pain patients. The authors proposed that pes planus was an important factor in the development of plantar fasciitis. Shama et al. (1983) drew similar conclusions in a retrospective review of 1000 patient radiographs, finding radiographic evidence of foot pronation in 81% of their 52 heel pain sufferers. While Messier and Pittala (1988) provided further support by demonstrating greater foot pronation in patients with plantar fasciitis with 2-dimensional motion analysis, neither foot pronation nor arch height were able to discriminate between subjects with and without heel pain. The authors concluded, therefore, that the link between foot pronation and plantar fasciitis was less definitive. Consequently, there remains considerable controversy regarding the role of arch mechanics in the development of plantar fasciitis.

The discrepancy between studies may, in part, reflect the inherent difficulty in assessing the shape and movement of the arch in vivo. To date, empirical studies have been primarily limited to either static measures of arch shape or indirect measures based on skin-mounted markers. However, neither radiographic nor conventional surface-marker techniques are suitable for accurately evaluating the shape or movement of the medial longitudinal arch during walking (Maslen and Ackland 1994; Wearing et al., 1998). Digital fluoroscopy, in contrast, provides the ability to dynamically track movement of the arch, in vivo, without the error of skin-movement artefact. The aim of the current study was to use digital fluoroscopy to investigate the sagittal plane motion of the arch in subjects with and without plantar fasciitis. It was hypothesised that subjects with plantar fasciitis would have a flatter foot and show greater arch elongation during gait.

METHODS

Subjects
The study included 10 patients (3 male and 7 female) with complaints of unilateral plantar heel pain and 10 asymptomatic volunteers individually matched on age, gender, and body weight. Criteria for inclusion into the patient cohort included localized tenderness isolated to the plantar fascial insertion and exacerbation of symptoms after periods of non-weightbearing. Patients were excluded if they presented with diffuse or bilateral heel pain, evidence of neural impingement, or a history of gout, inflammatory joint disease, trauma, or foot surgery.

Instrumentation
A digital fluoroscope (C-Vision multifunction fluoroscopy unit, Shimadzu, Kyoto, Japan) with a 16 inch image intensifier was used to record dynamic lateral radiographs of both feet during walking. Images were obtained using a radiation exposure of 1.2 mA per second at an intensity of 50 kV, thus limiting the equivalent dose to 60 µSv per patient. Optical distortion arising from the image intensifier was determined by using a rectilinear calibration grid consisting of lead shot, 2 mm in diameter, embedded within a Perspex screen to form 30 mm squares. Initial testing using both metallic and cadaveric calibration models indicated that the root mean square error in angular fluoroscopic measures was 0.2° following the application of a global distortion correction procedure (Baltzopoulos, 1995). The limits of agreement for repeated measurements in vivo were ± 0.5° and ± 0.6° for the AA and MPJ angles, respectively.

Sagittal sonograms of the plantar fascia of both feet were obtained using a variable frequency 12-5 MHz linear array transducer (HD1 5000, Advanced Technology Laboratories, Bothel, Washington, USA). The accuracy of sonographic measurements was evaluated by imaging a Perspex calibration model. Sonographic measures systematically underestimated calibration values. The mean error of in vitro sonographic measures was -0.5 ± 0.2 mm. The average bias for repeated measurements in vivo was -0.1 mm, with the limits of agreement ranging between 0.5 mm and -0.7 mm.

Procedures
The midgait method was used to acquire dynamic lateral radiographs from subjects while walking at a freely selected pace. Fluoroscopic images were analysed using MATLAB™ software. Two points for the calcaneus (C1, C2), first metatarsal (M1, M2) and hallux (H1, H2) were manually digitised for each image (figure 1). Coordinates for each point were reconstructed using a distortion correction procedure (Baltzopoulos, 1995) and were subsequently used to calculate the arch angle (AA) and the first metatarsophalangeal joint angle (MPJ) based on trigonometry (Figure 1). For each gait trial, the peak AA and MPJ occurring during the stance phase of gait were recorded. Sagittal movement of the arch was defined as the
aetiological factors in the development of plantar fasciitis

These data suggest that arch shape and motion are not

DISCUSSION

Significantly different from all other limbs (P < .05)

RESULTS

There was no significant difference in either the peak AA or the range of AA movement between limbs (table 1). However, subjects with plantar fasciitis were found to have a larger peak MPJ angle than control subjects (P < 0.05). While figure 2 shows that both the symptomatic and asymptomatic plantar fascia were thicker than those of control limbs (P < 0.05), significant correlations were noted between fascial thickness and the peak AA (r = 0.93, P < 0.05) and the peak MPJ angle (r = 0.79, P < 0.05) in the symptomatic limb only.

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\text{Table 1: Means (± SD) for the peak AA, angular change in the AA, and peak MPJ angle occurring during gait}
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<table>
<thead>
<tr>
<th>Variable</th>
<th>Units</th>
<th>Control (A)</th>
<th>Control (S)</th>
<th>Asymptomatic</th>
<th>Symptomatic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak AA</td>
<td>°</td>
<td>134.7 ± 10.0</td>
<td>135.7 ± 8.4</td>
<td>133.8 ± 8.0</td>
<td>137.4 ± 8.8</td>
</tr>
<tr>
<td>Change in AA</td>
<td>°</td>
<td>13.3 ± 3.0</td>
<td>12.7 ± 2.5</td>
<td>11.4 ± 1.8</td>
<td>12.0 ± 1.9</td>
</tr>
<tr>
<td>Peak MPJ</td>
<td>°</td>
<td>168.5 ± 3.9</td>
<td>168.9 ± 3.0</td>
<td>172.8 ± 5.8 *</td>
<td>173.5 ± 3.7 *</td>
</tr>
</tbody>
</table>

* Indicates a significant group effect (P < 0.05)

In contrast to control feet, the fascial dimensions of symptomatic feet were noted to be positively correlated with the peak arch angle during terminal stance, suggesting that the plantar fascia either assumed a more important role in arch support or was unable to withstand normal fascial loading. As proposed by Chandler and Kibler (1993) a relative loss of muscular support would increase the burden on passive structures of the foot, such as the plantar fascia, during gait. While weak ankle plantar flexors have been clinically linked with plantar fasciitis (Kibler et al., 1991), other studies have reported increased electromyographic activity in both the extrinsic and intrinsic foot muscles in painful conditions of the foot (Durant et al., 1985; Kayano, 1986). Moreover, in the current study, patients with heel pain were also observed to have a greater peak metatarsophalangeal joint angle during stance; suggesting a greater muscular activity within digital flexors. The concomitant discovery that the metatarsophalangeal joint angle was correlated with fascial thickness in only the symptomatic foot indicates that digital flexion most likely represents an antalgic response, with the toe flexors acting as an additional brace to the medial longitudinal arch and thereby reducing stress within the plantar fascia. In support of this concept, both the intrinsic and extrinsic muscles of the foot have been reported to decrease the load borne by the plantar fascia (Hamel et al., 2001, Salathe and Arangio, 2002). The findings are also consistent with our earlier study evaluating ground reaction forces in plantar fasciitis in which patients exhibited an earlier and greater loading of the toes during gait (Wearing et al., 2003).
Further experimental work incorporating electromyographic analysis, however, would be required to ascertain the distribution of internal load between the intrinsic and extrinsic digital flexors and the plantar fascia.

Similar to the findings of Tsai et al. (2000), the current study noted an increased fascial thickness in both the symptomatic and asymptomatic limb of heel pain patients when compared to control subjects. Although fascial thickening in the symptomatic foot is consistent with sonographic findings of plantar fasciitis (Gibbon and Long, 1999), the attendant increase in the thickness of the asymptomatic fascia, albeit to a lesser extent, suggests that the condition may represent a bilateral process. While it might be argued an increased fascial thickness in the asymptomatic limb may reflect a compensatory rise in loading of the contralateral foot, the present study found no correlation between arch movement and fascial thickness, or any evidence of altered loading of the asymptomatic foot of patients. It would appear, therefore, that despite having similar arch mechanics, heel pain patients have inherently thickened plantar fascia when compared to age and weight matched control subjects. Hypothetically, the bilateral increase in the diameter of the fascia may denote a global change in the material properties of the connective tissue structures, similar to that proposed in tendinopathy, rendering it less capable of resisting normal tensile load and more susceptible to injury (Järvinen et al., 1997; Sano et al., 1997). The increase in the fascial dimensions of the asymptomatic limb (0.07 cm), however, was marginal considering the RMS error and limits of agreement for repeated sonographic measures was 0.03 cm and ± 0.06 cm, respectively.

**CLINICAL RELEVANCE**

Arch mechanics are a permissive, rather than inciting, factor in plantar fasciitis. Consequently, treatments aimed at changing the shape of the arch may offer a method of modifying the severity of heel pain, but are unlikely to address the initial cause of the injury, which remains unknown.

**REFERENCES**


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