Gait abnormalities following rupture of the tendo Achillis

A PEDOBAROGRAPHIC ASSESSMENT

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One of the factors that influence the outcome after rupture of the tendo Achillis is abnormality of gait. We prospectively assessed 14 patients and 15 normal control subjects using an in-shoe plantar pressure measurement system. There was a significant reduction in peak mean forefoot pressure in the early period of rehabilitation (p < 0.001). There was a concomitant rise in heel pressure on the injured side (p = 0.05). However, there was no difference in cadence, as determined by the duration of the terminal stance and pre-swing phases as a proportion of total stance. The forefoot pressure deficit in the group with tendon ruptures was smaller when assessed six months after the injury but was still significant (p = 0.029). Pedobarographic assessment confirms that there are marked abnormalities within the gait cycle. Rehabilitation programmes which address these abnormalities may improve outcome.

Rehabilitation after rupture of the tendo Achillis is slow. The average return to sport is about six to nine months. For elite athletes it is a career-threatening injury. Only 50% to 60% of non-elite sportsmen ever return to their full pre-injury activities, and this figure may be even less in non-operatively treated patients. Although the majority of patients report good long-term results, there are many who have persistent debilitating symptoms for years.

One of the key factors that limits recovery is an abnormality of gait. In extreme cases, weakness in the calf muscles or lengthening of the tendon may be responsible. However, in many cases the cause is less clear cut. Assessment of a disturbance of gait is a complex process, perhaps explaining why this aspect of rehabilitation has rarely been given attention.

Measurement of plantar pressure is an important part of the assessment of gait. The advent of new techniques of pedobarography has facilitated more accurate analysis. The earliest designs used pressure sensitive mats to quantify the pressures under the foot during barefoot walking, but more recently the important role of footwear in dispersing load has been established. Hence, many modern systems use in-shoe pressure analysis. These have been shown to measure plantar pressures reliably during the gait cycle.

The primary aim of this investigation was to quantify the acute changes in plantar pressure measurements after rupture of the tendo Achillis. The secondary question was whether these changes persisted in the medium term. In order to answer these questions, patients were compared to normal control subjects using an in-shoe measurement system.

Patients and Methods
This study had the approval of the local research ethics committee. Fifteen consecutive patients with acute rupture of the tendo Achillis were asked to provide plantar pressure measurements. One patient declined to enter the study. The mean age of the patients was 48 years (31 to 71). Three women and 11 men were assessed; eight had operative repair of the tendon rupture and six had non-operative treatment.

All patients had been treated in traditional serial equinus plaster-of-Paris casts, where the equinus of the foot was reduced over time until the patient achieved a plantigrade position. Weight-bearing within the cast was only permitted for the last two weeks. All patients were assessed two weeks after the removal of their plaster cast. For the patients who had operative repair, assessment was at ten weeks. For those treated non-operatively assessment was at 14 weeks. At this stage, patients would be expected to be fully weight-bearing but any abnormality of gait would still be evident. Each patient was then invited to have a second scan six months after their tendon rupture.
Fifteen people (five men) with no history of lower limb abnormalities were used as controls. The mean age of the control group was 40 years (21 to 57).

The F-scan system (Tekscan Incorporated, Boston, Massachusetts) uses thin in-shoe pressure pads to record plantar pressures (Fig. 1). The pressure pads have four sensors per cm\(^2\) and a sampling frequency of 500 Hz. The pads were sized according to the patients shoe size and carefully placed inside the shoe to avoid any creases because folding of the pressure cells may cause artefacts in the recording. The patients wore their own shoes and the same shoes for each assessment.

The in-shoe pressure sensors were calibrated to adjust for the patients’ weight before each measurement. The patients were then asked to walk in a straight line along a flat corridor at their normal walking speed. Ten cycles were recorded and the fourth, fifth and sixth cycles extracted for analysis. If one of these cycles contained an artefact then the seventh cycle was used instead. The measurements were recorded as the mean of the three cycles.

Since the tendo Achillis transmits the plantar flexion torque of the gastrocnemius and soleus muscles the analysis was focused upon the terminal stance and pre-swing phases of the gait cycle. During these phases the muscles are actively contracting. The terminal stance phase begins when the patient’s centre of gravity lies over the centre of the foot and the pre-swing phase ends when the toes leave contact with the floor. In terms of plantar pressure, the sole of the foot was divided into three areas according to the International Guidelines for Plantar Pressure Measurements. The forefoot area was defined as the distal 40% of the length of the foot and the heel area as the proximal 30%.

Two variables were assessed. First, the duration of the terminal stance and pre-swing phases as a proportion of the total stance component of the gait cycle. Secondly, the mean and maximum peak plantar pressures within the forefoot and heel areas. Each measurement is given as a percentage of the value recorded for the uninjured (contralateral) limb, thus the analysis is based upon the difference between the injured and uninjured limb.

A \( t \)-test was used to compare the difference in means between the two groups. The test was performed for the data collected two weeks after the treated group had their plaster removed and again six months after injury. A \( p \) value \( \leq 0.05 \) was considered significant.

### Results

Table I shows the differences between the two groups as measured two weeks after the plaster casts were removed. As expected, the control group had a symmetrical gait pattern. There was less than 2% difference between the limbs in terms of both foot pressures and the duration of the terminal stance and pre-swing phases of the gait cycle. In con-

<table>
<thead>
<tr>
<th>Difference between limbs</th>
<th>Control group (n = 15)</th>
<th>Tendo Achillis group value (n = 14)</th>
<th>( p ) value</th>
<th>95% CI*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean peak heel pressure (SD)</td>
<td>0.6 (26)</td>
<td>-39.6 (42)</td>
<td>0.05</td>
<td>-66 to -14</td>
</tr>
<tr>
<td>Maximum peak heel pressure (SD)</td>
<td>0.9 (16)</td>
<td>-4.6 (14)</td>
<td>0.34</td>
<td>-17 to 6</td>
</tr>
<tr>
<td>Mean peak forefoot pressure (SD)</td>
<td>-1.7 (16)</td>
<td>33.4 (23)</td>
<td>&lt; 0.001</td>
<td>20 to 50</td>
</tr>
<tr>
<td>Maximum peak forefoot pressure (SD)</td>
<td>-1.5 (18)</td>
<td>33.1 (31)</td>
<td>0.001</td>
<td>16 to 54</td>
</tr>
<tr>
<td>Terminal stance + pre-swing/total stance phase (SD)</td>
<td>1.8 (16)</td>
<td>10.9 (14)†</td>
<td>0.14</td>
<td>-3 to 21</td>
</tr>
</tbody>
</table>

* CI, confidence interval
† n = 12 (two scans could not be interpreted due to poor quality recordings)
The group with a ruptured tendo Achillis showed marked asymmetry between the injured and unaffected limbs. There was a 33% decrease in the mean peak forefoot pressure on the injured side and a concomitant 40% increase in mean peak heel pressure. The difference between the groups was statistically significant for the increase in heel pressure (p = 0.05) and very highly significant for the decrease in forefoot pressure (p < 0.001). There was no statistical difference between the groups in terms of the duration of the terminal stance and pre-swing phases.

Table II shows the differences between the control group and the treated group six months after their injury. Only 11 of the 14 patients provided repeat scans at this stage. The mean peak forefoot pressure deficit of the injured limb had reduced from 34% to 18% in the tendo Achillis group. However, both this and the associated increase in heel pressure remained statistically significantly different from the control recordings.

**Discussion**

In one of the few previous assessments of plantar pressures after injury to the tendo Achillis, McComis et al.\(^5\) used force mats to assess asymmetry of gait. They detected no significant differences in plantar pressure between the injured and uninjured legs, but were only able to assess five patients. In contrast Neumann et al.\(^5\) detected abnormalities in both cadence and pressure when comparing control subjects with ten patients who had sustained an injury one year previously. This study used a hydraulic pressure distribution system.

Our study was designed to quantify the gait abnormalities found after rupture of the tendo Achillis. The pedobarographic measurements confirm that patients have a highly statistically significant deficit in mean peak forefoot pressure in the early stages of rehabilitation. This finding implies weakness in the musculotendinous units that provide plantar flexion torque at the ankle joint. The muscle weakness and the resulting loss of symmetry within the gait cycle produces a less energy efficient walking pattern. This is consistent with the limited walking distance and diffuse aching in the calf that affects many patients.

The deficit of forefoot pressure is associated with a concomitant increase in the mean peak heel pressure on the affected side. This may explain the heel pain that also affects patients, particularly in the early stages of rehabilitation.

The second pedobarographic recordings, taken six months after the injury, show some improvement in the symmetry between the injured and uninjured foot pressures. However, even at this stage, there is still a statistically significant deficit in peak forefoot pressure. This confirms the findings of the only previous study to assess the long-term effect of rupture of the tendo Achillis on plantar pressures.\(^1\)

The pressure recordings did not show any differences between the control and rupture subjects in terms of the duration of the terminal stance and pre-swing phases, as a proportion of the total cycle time. This suggests that the gait abnormalities are manifest as a pressure deficit rather than an abnormality of cadence.

The major limitation of the study is the use of pedobarography as the only assessment of gait. Plantar pressures are only one part of gait analysis and further investigations would be required to fully appreciate the problems caused by rupture of the tendo Achillis. However, the major functional deficit after such an injury lies within the musculotendinous unit of the calf. Since this unit supplies the main plantar flexion torque at the ankle joint, it seems reasonable to begin with an assessment of the resulting plantar pressure deficit.

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The patients in this study included both operatively and non-operatively managed ruptures. The number of patients did not allow a subgroup analysis to assess the differences between these groups. However, since all of the patients were managed with non-weight-bearing plaster casts the early deficits in peak forefoot pressure are likely to affect both groups. Further analysis, ideally as part of a randomised trial, would be required to compare the long-term plantar pressure effects of operative versus non-operative management.

Several authors have cited weakness in the gastrocnemius and soleus muscles as a cause of delayed recovery after rupture of the tendo Achillis.\(^1,2,4,5\) The reduction in peak plantar pressure within the forefoot noted in this study, supports their view. In addition, our investigation suggests that there is a concomitant increase in heel pressure on the affected side. Although these abnormalities appear to improve with time, they are still evident six months after the injury. This has implications for clinical practice. If interventions in early rehabilitation were targeted at these areas in particular, then poor long-term outcomes may be avoided.

<table>
<thead>
<tr>
<th>Difference between limbs</th>
<th>Control group (n = 15)</th>
<th>Tendo Achillis group (n = 11)</th>
<th>p value</th>
<th>95% CI*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean peak heel pressure (SD)</td>
<td>0.6 (26)</td>
<td>-35.5 (39)</td>
<td>0.009</td>
<td>-62 to -10</td>
</tr>
<tr>
<td>Maximum peak heel pressure (SD)</td>
<td>0.9 (16)</td>
<td>-17.7 (27)</td>
<td>0.061</td>
<td>-38 to 10</td>
</tr>
<tr>
<td>Mean peak forefoot pressure (SD)</td>
<td>-1.7 (16)</td>
<td>17.6 (18)</td>
<td>0.012</td>
<td>5 to 33</td>
</tr>
<tr>
<td>Maximum peak forefoot pressure (SD)</td>
<td>-1.5 (18)</td>
<td>14.7 (17)</td>
<td>0.029</td>
<td>2 to 31</td>
</tr>
<tr>
<td>Terminal stance + pre-swing/total stance phase (SD)</td>
<td>1.8 (16)</td>
<td>6.0 (7)</td>
<td>0.43</td>
<td>-7 to 15</td>
</tr>
</tbody>
</table>

* CI, confidence interval
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References