Plantar Pressure Distribution Analysis in Normal Weight Young Women and Men With Normal and Claw Feet: A Cross-Sectional Study

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We analyzed the plantar support in 72 normal-weight young voluntaries (46 women, 26 men), by a baropodometric platform. We considered subjects with claw foot (CFS) and subjects with normal foot (NFS). We found a significant reduction of total plantar support surface in the CFS ($P < 0.0001$ for women, $P < 0.001$ for men), due to the reduction of the forefoot and rear foot areas of both plantar imprints. Indeed, CFS of both sexes exhibited higher values of both plantar pressure and peak pressure, compared to the NFS. Moreover, the load per units of plantar surface increased in CFS compared to the NFS. In conclusion, the reduction of plantar support surfaces in CFS of both sexes was associated to a major load per units of plantar surface in the forefoot and rear foot areas, and this may be a risk factor to lower extremity overuse injuries. Clin. Anat. 18:245–250, 2005. © 2005 Wiley-Liss, Inc.

Key words: baropodometer; claw foot; plantar pressure distribution

INTRODUCTION

Claw foot is a clinical condition of plantar support with absence or reduction of support on the ground of midfoot (isthmus). Podogram, baropodometer, and X-ray imaging can help in its clinical identification and distinguishing between different levels of claw foot identified in the study of Filipe (1993). Many factors can be responsible for the claw foot. The congenital claw foot can be caused by plantar flexion of the first ray, as shown by Schuster (1939). Spasticity or contraction of the peroneus longus muscle can induce claw foot by a plantar flexion of first ray, like other conditions in the study of Root et al. (1977) including hyposthenia or flaccid paralysis of peroneus brevis or peroneus longus muscles, spasticity of tibialis anterior muscle, contraction of tibialis posterior muscle. In neurologic involvement (spasticity), the peroneus longus muscle action leads to claw foot deformity, commonly evidenced in conditions such as Charcot Marie Tooth Disease.

In children, the claw foot can be temporarily present and disappear or correct itself during adolescence, as shown by ScLuster (1958). Mono- or bi-lateral claw feet can be clinically silent or associated with different diseases and the condition is considered a specific risk factor for different pathologies of bones, joints, and muscles, such as the plantar fasciitis (see Warren et al., 1984, 1987). Using a baropodometer, the present study verifies the influence of bilateral claw foot on the plantar support surfaces and loads in normal weight subjects of both sexes, excluding overweight and obesity, which significantly modify the plantar support (Hills et al., 2001; Gravante et al., 2003).

MATERIALS AND METHODS

We randomly selected 72 normal weight voluntary subjects (29 women and 16 men with normal feet, 17 women and 10 men with bilateral claw foot).

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We recorded the body weight to the nearest 100 g using a balance (SECA 709, Hamburg, Germany), and the stature to the nearest 1 mm using a wall-stadiometer (SECA 220, Hamburg, Germany). Considering the indications of the World Health Organisation (1998), the body mass index (BMI = kg/m²; normal weight subjects = 18.5–24.9) was calculated to exclude preliminarily from the study overweight (25 < BMI ≤ 29.9) and obese (BMI ≥ 30) subjects. We also excluded the subjects with orthopaedic and nervous pathologies considering their familiar and personal medical history. The same researcher carried out an accurate objective examination of the spine (using scoliosometer Chinesport, Udine, Italy), the limbs, and the sensory organs (using Fukuda and Romberg tests, opened and closed mandible tests, Barrè vertical test). We excluded subjects with spine, limbs, and sensory deficits.

The evaluation of ground midfoot contact for each foot was based on the I:FW ratio between the least midfoot width (or isthmus, I) and the greatest forefoot width (FW), measured to the nearest mm on the paper copy of the plantar imprints recorded with a force platform (Fig. 1); an I:FW ratio = 0 for both foot imprints was indicative of bilateral claw foot and an I:FW ratio comprised between 0.33 and 0.66 for both foot imprints was indicative of bilateral normal foot. We excluded subjects with unilateral claw foot.

![Fig. 1. Geometric measurements on plantar imprints recorded with the force platform: D, the orthogonal distance of the CP from the tangent line to the rear edge; FW, the greatest forefoot width; I, the least midfoot width (isthmus); RW, the greatest rear foot (posterior heel) width; L, maximum length of plantar imprints. Plantar imprint is divided into two regions, forefoot area (FA) and rear foot area (RA), through an axis positioned on the point graphically representing the mean location of the CP during the recording 5-sec time interval. Force vectors are represented as percentages of the peak pressure (M) with different sizes and colors, according to a chromatic scale.](image-url)
foot, bilateral incomplete claw foot, and unilaterally bilateral flat foot (L:F ratio > 0.66). On the paper copy, we also measured the maximum length (L) of plantar imprints and the maximum width of rear foot area (RW), equivalent to posterior heel.

For the pressure distribution analysis, we used an electronic modular clinical baropodometer (BPE model 120, Physical Support, Milan, Italy). This instrument has three components: (1) a 40-cm wide modular platform, composed by three elements, the central one being 120 cm long and containing 4,800 rigid sensors; each sensor area is 1 cm², for a total surface of 4,800 cm² (one sensor per cm² resolution); sensors are part of a matrix of active resistance incorporated in an electronic circuit and covered with an “artificial skin,” a layer of conductor rubber, of a known thickness, which deforms under the pressure of the feet (the rubber transmits the load applied to the underlying sensors, recording plantar pressures up to 100 kg/cm²); (2) a computer with a 200 Mhz Pentium processor and a SVGA video card, which records and analyses the sensors input (pressure/current) through a specific program (Physical Gait Software, San Diego, CA). The P-value was considered to be statistically significant when <0.05.

**RESULTS**

Age and biometrical data of the subjects of both sexes are shown in Table 1. As expected, no statistically significant difference was evidenced between the groups.

Table 2 shows the plantar surfaces recorded with the baropodometric platform. In both sexes, the group with claw feet (CFS) exhibited a significantly lower total plantar support surface ($P < 0.001$ for women, $P < 0.001$ for men) compared to subjects with normal feet (NFS), due to a reduction in both the plantar imprints of the rear ($P < 0.0001$ for women, $P < 0.0005$ for men) and forefoot ($P < 0.005$ for women, $P < 0.01$ for men) areas.

**TABLE 1. Age and Biometrical Data of the Groups**

<table>
<thead>
<tr>
<th></th>
<th>Women with normal foot ($n = 29$)</th>
<th>Women with claw foot ($n = 17$)</th>
<th>$P$-value</th>
<th>Men with normal foot ($n = 16$)</th>
<th>Men with claw foot ($n = 10$)</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>22.00 ± 3.15</td>
<td>22.59 ± 4.12</td>
<td>NS</td>
<td>24.25 ± 5.05</td>
<td>25.00 ± 5.94</td>
<td>NS</td>
</tr>
<tr>
<td>Stature (cm)</td>
<td>160.32 ± 6.58</td>
<td>159.10 ± 7.25</td>
<td>NS</td>
<td>176.45 ± 7.85</td>
<td>175.45 ± 5.54</td>
<td>NS</td>
</tr>
<tr>
<td>Body weight (kg)</td>
<td>55.79 ± 7.09</td>
<td>55.88 ± 8.83</td>
<td>NS</td>
<td>69.84 ± 9.33</td>
<td>68.15 ± 6.56</td>
<td>NS</td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>21.62 ± 1.48</td>
<td>22.07 ± 3.06</td>
<td>NS</td>
<td>22.36 ± 1.88</td>
<td>22.12 ± 1.66</td>
<td>NS</td>
</tr>
</tbody>
</table>

*Mean ± SD; NS, no significance.

**TABLE 2. Plantar Surfaces Recorded to Baropodometer**

<table>
<thead>
<tr>
<th></th>
<th>Women with normal foot ($n = 29$)</th>
<th>Women with claw foot ($n = 17$)</th>
<th>$P$-value</th>
<th>Men with normal foot ($n = 16$)</th>
<th>Men with claw foot ($n = 10$)</th>
<th>$P$-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right plantar surface</td>
<td>130.83 ± 11.57</td>
<td>105.41 ± 15.68</td>
<td>&lt;0.0001</td>
<td>151.44 ± 14.28</td>
<td>121.80 ± 17.26</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Left plantar surface</td>
<td>125.31 ± 12.50</td>
<td>111.12 ± 12.67</td>
<td>0.0006</td>
<td>149.06 ± 16.32</td>
<td>128.00 ± 21.94</td>
<td>0.0098</td>
</tr>
<tr>
<td>Forefeet surface</td>
<td>141.41 ± 14.42</td>
<td>126.18 ± 16.20</td>
<td>0.0019</td>
<td>167.00 ± 16.92</td>
<td>146.90 ± 19.12</td>
<td>0.0098</td>
</tr>
<tr>
<td>Rear feet surface</td>
<td>114.72 ± 8.58</td>
<td>90.35 ± 11.83</td>
<td>&lt;0.0001</td>
<td>133.50 ± 13.16</td>
<td>102.90 ± 21.58</td>
<td>0.0001</td>
</tr>
<tr>
<td>Total surface</td>
<td>256.14 ± 21.33</td>
<td>216.53 ± 26.58</td>
<td>&lt;0.0001</td>
<td>300.50 ± 28.73</td>
<td>249.80 ± 38.88</td>
<td>0.0008</td>
</tr>
</tbody>
</table>

*Mean ± SD; cm².
Table 3 shows the plantar loads recorded with the baropodometric platform. Women with claw feet exhibited significantly greater values (g/cm²) on the forefoot and rear foot areas, M peak, and mean pressure compared to women with normal feet. Similarly, men with claw feet exhibited significantly greater values (g/cm²) on the forefoot and rear foot areas, M peak, and mean pressure compared to men with normal feet. Relative to % load distribution of all groups, there was no difference between the feet, whereas we found a significant % overload in forefoot areas in CFS (P < 0.05 for women, P < 0.005 for men) compared to NFS. Consequently, in both sexes, the CFS had a reduction of % load on the rear foot areas. For all groups, the M peak was mainly located in the right posterior heel and resulted greater in subjects with claw feet (P < 0.001 for women, P < 0.05 for men) compared to subjects with normal feet; the same applied for the plantar mean pressure (P < 0.005 for women, P < 0.05 for men). Table 3 also shows the load (g) for units of plantar surface recorded by baropodometric platform: women with claw feet exhibited significantly greater values on the forefoot (P < 0.005) and rear foot areas (P < 0.05), compared to men with normal feet.

Table 4 shows the linear values of the plantar imprints of all groups. As expected, in both sexes, the groups with bilateral claw feet exhibited a I:FW ratio = 0; moreover, the same groups exhibited a significant reduction of right (P < 0.01 for women, P < 0.05 for men) and left (P < 0.05 for both sexes) width of anterior heel, and a significant reduction of right (P < 0.05 for women, P < 0.0005 for men) and left (P < 0.01 for women, P < 0.05 for men) width of posterior heel. In both sexes, the groups with claw feet exhibited a significant reduction of length of right (P < 0.05 for both sexes) and left (P < 0.05 for both sexes) plantar imprints.

**DISCUSSION**

In previous studies, Gravante et al. (2000, 2001) analyzed the plantar support of both sexes with the baropodometric platform, standardizing the reference values for plantar areas and loads. Ridola et al. (2000, 2001a, 2001b) and Russo et al. (1999) showed the influence of a regular physical activity and of the body weight on the plantar support, confirming the important diagnostic and clinical value of the baropLOOP-ing.
podometric platform, as shown by Pomara et al. (2002). We wanted to progressively analyze the different patterns of plantar support in both sexes, such as claw foot, to identify peculiar pressure patterns predisposing to musculoskeletal pathologies.

The study of Cole (1983) indicated several forms of claw foot, with specific anatomical features and different outcomes. This deformity is often associated with scoliosis and it may be secondary to altered balance or to disorders of the central nervous system, as shown by Carpintero et al. (1994). In a multidisciplinary study of Tynan et al. (1992), it was found that in the majority of cases of claw foot, the peroneal compartment was enlarged in relation to the anterior compartment when compared to the normal controls. Recent studies have shown that claw foot is one of the risk factors, including also flat foot, restricted ankle dorsiflexion, increased hind foot inversion, to predispose people toward lower extremity overuse injuries, as indicated by the studies of Kaufman et al. (1999) and Keegan et al. (2002).

To the best of our knowledge, this is the first research in which a baropodometric platform was used to study the bilateral claw feet in young normal weight subjects of both sexes, comparing them to controls. In the study of Sneyers et al. (1995), it was shown that the relative load of the forefront in athletes with claw foot was higher compared to controls.

**CONCLUSION**

Our study indicates that claw foot is associated with a significant reduction of the plantar support surface in young normal weight sedentary subjects of both sexes; these data were expected because probably associated with a peculiar redistribution of body weight on the plantar support, being a different % load between forefront and rear foot. In the smaller forefront and rear foot areas, the subjects with claw feet exhibited an increased load, particularly on the forefront areas, according to Sneyers’s study (1995). In conclusion, the reduction of plantar support surfaces in CFS of both sexes was associated to a major load per units of plantar surface in the forefront and rear foot areas, and this may be a risk factor to lower extremity overuse injuries. In fact, Dawson et al. (2002), Sosenko (2002), Olson et al. (2003), and Kernozek et al. (2003) already evidenced that claw foot, with other foot deformities, is a risk factor for pathologies of inferior limbs. Further studies would be necessary to confirm whether claw foot is associated with modifications of the posture or gait.

**REFERENCES**


