The Diagnostic Value of Pedobarography

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Pedobarography can quantify static and dynamic foot pressure. Despite an increase in the clinical use of pedobarography, the results and the clinical diagnosis do not always correlate, leading to confusion and misdiagnosis. The authors evaluated the potential of pedobarography to diagnose several diseases associated with abnormal pressure across the plantar surface. The study included 72 patients (96 cases) between January 2009 and August 2012 with symptoms of excessive plantar pressure. The average age was 50.9 years (range, 18-92). Patients had the lesion for an average of 17 months (range, 8-29). Pedobarographic measurements were used to evaluate the compatibility between the highest pressure on pedobarography and the clinical peak pressure with plantar ulcers or calluses. Maximal peak pressure was evaluated by static and dynamic measurements using numeric and graphic measurements in pedobarography. The diagnostic validity of pedobarography was analyzed by comparing clinical peak pressure and pedobarographic measurements. The diagnostic validity of pedobarography was 17.7% to 51% for static measurement and 13.5% to 49% for dynamic measurement. The diagnostic validity of pedobarography was low for intractable plantar keratosis and metatarsal head callus associated with metatarsophalangeal dislocation in rheumatoid arthritis. However, it was 57% to 100% for Charcot arthropathy with midfoot ulcers. When used to compare numeric pressure and graphic peak pressure for each part of the foot, pedobarography showed low diagnostic correlation. Based on the study results, the diagnostic validity of pedobarography is low. [Orthopedics. 2014; 37(12):e1063-e1067.]

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Pedobarography was first developed in the 1960s and has been enhanced with the advancement of computing technology.1,2 Today, pedobarography is used in a clinical context because it can provide both static and dynamic plantar pressure measurements of the foot during biomechanical tests.1,2 Recent studies indicate that pedobarography analyses are required to isolate the particular areas of stress in the sole of the foot to identify the cause of pain.3 Despite an increase in the clinical use of pedobarography, the results and the clinical diagnosis do not always correlate, leading to confusion and misdiagnosis. Schmiegel et al4 evaluated foot pressure in 112 patients with rheumatoid arthritis. Their study showed that pedobarography did not score the highest pressure values in the areas of severe pain and that it was therefore of no clinical relevance. A key limitation of pedobarography is its inability to detect a patient’s habit of avoiding pressure in the area of pain that leads to an antalgic gait.5 An altered gait pattern can affect pressure scores and provide contradictory information on areas of pain. In addition, changes in the number of examinations or the analysis techniques in the same patient can cause discrepancies in scores.6,7

Contradictory findings have resulted in uncertainty about the diagnostic significance of pedobarographic analysis and its suitability for the diagnosis of various conditions related to foot pressure. Chronic ulcers or calluses show clinical peak pressure, and clinicians use pedobarography to measure foot pressure. The goal of the current study was to investigate whether pedobarography can effectively diagnose various conditions related to foot pressure. Additionally, the authors attempted to correlate these conditions with the results of pedobarography.

**Materials and Methods**

A total of 96 feet (72 patients) with plantar calluses or ulcers were enrolled in this study from January 2009 to August 2012. The average patient age was 50.9 years (range, 18-92).

Patients had the lesion for an average of 17 months (range, 8-29). Three of 10 patients with a midfoot ulcer had diabetes mellitus, and another 7 patients had Charcot arthropathy with diabetes mellitus. Of 49 patients with intractable plantar keratosis, 37 had intermittently used insole or metatarsal pads. Only 1 patient with Charcot arthropathy had used canes before visiting the clinic.

Laboratory peak pressure area values were evaluated with pedobarography. The 3 data categories analyzed were (1) clinical peak pressure area (determined by physical examination); (2) numeric peak pressure area (determined with pedobarography); and (3) graphic peak pressure area (determined with pedobarography). All patients with suspected ulcers or calluses were examined by the same orthopedic foot specialist (H.S.L.).

The 3 most common pathologic conditions were intractable plantar keratosis (68 cases); midfoot ulcer associated with Charcot arthropathy (7 cases); and metatarsal head calluses associated with metatarsophalangeal dislocation in rheumatoid arthritis (11 cases). Other conditions included diabetic foot ulcer (10 cases), Lisfranc joint arthritis in flatfoot, and partial foot amputation. These causes were excluded from analysis because they occurred in fewer than 5 cases.

For each patient, foot pressure was measured blindly by the same technician, using Gaitview (Alfooys, Seoul, Korea). For measurement of static (standing) foot pressure, patients were asked to stand face-forward for 20 seconds and the average foot pressure during the period was calculated. For dynamic (walking) foot pressure, patients were asked to walk normally in the center of a platform that was 1 m wide and 5 m long. Dynamic foot pressure was determined by having patients repeat the procedure 5 times. The numeric pressure scores (kilopascals) determined for the static and dynamic phases were calculated with data obtained from detailed analysis of foot loading. The numeric pressure scores were subdivided into 8 regions (first toe, second through fifth toes, first metatarsal head, second through fourth metatarsal heads, fifth metatarsal head, midfoot, medial heel, and lateral heel).
The graphic pressure of both static and dynamic foot loading was also analyzed by observing color changes on the footprints (Figure 1). Pressure distribution in the footprints was shown in green, yellow, and red, with increasing pixel counts indicating increased loading. Moreover, the graphic peak pressure area associated with the highest pressure point was indicated as a black dot for easy classification (Figure 2). The authors analyzed the correlation between numeric pressure scores obtained from the pedobarographic measurements and the areas with plantar ulcers or calluses identified on physical examination. The authors investigated whether the graphic peak pressure data from the footprints correlated with clinical peak pressure. In patients with a normal stance or gait, foot loading tends to be higher in the heel region than in other parts of the foot. Because this increased pressure produces false-positive results, the authors further scrutinized the correlation by eliminating the possible false-positive heel region.

**RESULTS**

The highest numeric pressure scores correlated with findings on physical examination in 17 cases (17.7%) for static measurement and 13 cases (13.5%) for dynamic measurement. After the false-positive heel region was eliminated, this correlation increased to 49 cases (51%) for static measurement and 47 cases (49%) for dynamic measurement.

Maximal peak pressure of the graphic footprints correlated with findings on physical examination in 40 cases (41.7%) for static measurement and 30 cases (31.3%) for dynamic measurement.

The correlation for all patients was 13.5% to 51%, with static measurement producing better correlation than dynamic measurement. This graphic correlation was significantly higher than the numeric correlation including the heel (P<.01). However, no significant difference was found between graphic correlation and numeric correlation excluding the heel (static measurement, P=.136; dynamic measurement, P=.095) (Table).

The 3 most common pathologic conditions that can affect the foot, intractable plantar keratosis, midfoot ulcer associated with Charcot arthropathy, and metatarsal head calluses associated with metatarsophalangeal dislocation in rheumatoid arthritis, were analyzed.

Analysis of 68 cases of intractable plantar keratosis showed a correlation between numeric pressure scores and heel data in 8 cases (12%) for static measurement and 8 cases (12%) for dynamic measurement.

When heel data were excluded, the number of cases showing correlation increased to 30 (44%) for static measurement and 34 (50%) for dynamic measurement. Correlation between the symptomatic area and graphic peak pressure was similar to the total patient correlation, in 23 cases (34%) for static measurement and 20 cases (29%) for dynamic measurement (Table).

Analysis of 7 cases of midfoot ulcer associated with Charcot arthropathy showed a high correlation between the symptomatic area when heel data were included, with correlation evident in all cases (100%) for static measurement and 4 cases (57%) for dynamic measurement.

### Table

<table>
<thead>
<tr>
<th>Pathologic Condition</th>
<th>Numeric Correlation Including Heel</th>
<th>Numeric Correlation Excluding Heel</th>
<th>Graphic Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total, No.</td>
<td>Static 17 (17.7%) Dynamic 13 (13.5%)</td>
<td>Static 49 (51%) Dynamic 47 (49%)</td>
<td>Static 40 (41.7%) Dynamic 30 (31.3%)</td>
</tr>
<tr>
<td>Intractable plantar keratosis, No.</td>
<td>8 (12%) Dynamic 8 (12%)</td>
<td>30 (44%) Dynamic 34 (50%)</td>
<td>23 (34%) Dynamic 20 (29%)</td>
</tr>
<tr>
<td>Charcot arthropathy, No.</td>
<td>Static 7 (100%) Dynamic 4 (57%)</td>
<td>Static 7 (100%) Dynamic 5 (71%)</td>
<td>Static 7 (100%) Dynamic 4 (57%)</td>
</tr>
<tr>
<td>Rheumatoid arthritis, No.</td>
<td>2 (18%) Dynamic 1 (9%)</td>
<td>5 (45%) Dynamic 6 (55%)</td>
<td>8 (73%) Dynamic 2 (18%)</td>
</tr>
</tbody>
</table>
graphic peak pressure was observed in 7 cases (100%) for static measurement and 4 cases (57%) for dynamic measurement (Table).

The 11 cases of metatarsal head callus associated with metatarsophalangeal dislocation in rheumatoid arthritis showed mixed correlation, whereas analysis of numeric pressure scores with heel data showed no correlation. Analysis showed correlation in 2 cases (18%) for static measurement and 1 case (9%) for dynamic measurement with heel data and in 5 cases (45%) for static measurement and 6 cases (55%) for dynamic measurement without heel data.

Correlation of graphic peak pressure was higher than numeric pressure scores in 8 cases (73%), whereas dynamic measurement showed correlation in 2 cases (18%) (Table).

DISCUSSION

Several foot diseases, such as calluses and ulcers, are caused by abnormally high foot pressure across the plantar surface. The authors assessed the diagnostic value of pedobarography in patients with foot calluses or ulcers by the correlation between the symptomatic area and the maximal peak pressure on pedobarographic measurements. Pedobarography can be used to determine clinical outcome or to monitor the progress of rehabilitation, but pedobarography had limited use as a diagnostic tool in this study.

Pedobarography attracted much attention at the time of its development. Its ability to measure foot pressure directly led to the expectation that it might significantly aid in diagnosis. Despite this initial enthusiasm, the possibility of error in the measurement process emerged during the initial stages of pedobarography. Holmes and Timmerman indicated that measurement time and measurement trials affected the values obtained. Earlier researchers also raised the issue of discrepancies in measured values. In addition, Holmes and Timmerman suggested that the testing environment and the level of experience of the practitioner may also affect measurement results. Bogdan reported difficulty in obtaining the same foot pressure as that obtained during normal walking when subjects stepped on equipment that was placed in the middle of the walking path. Moreover, when the foot pressure of the first walking step was measured, it was difficult to account for pressure changes over the course of the walking path.

Insole-type pedobarography and pedobarography performed with sensors attached to the soles of the feet were developed to account for these difficulties. However, Lord noted that it was difficult to attach sensors in the correct location.

When pedobarography is used clinically, measurement errors can occur as a result of the factors discussed earlier. The causes of these errors are being investigated by the current authors and others to prevent them from affecting future measurements. However, if a patient walks abnormally when being monitored by the measuring device, maximal peak pressure may be recorded in areas other than the site of the primary symptom. If the patient has difficulty stepping accurately because of pain at the time of measurement or if repeat practice walking incurs pain and the patient exhibits an antalgic gait, the patient is led to walk while exerting abnormal pressure on the area of pain. In this case, repeat trials cannot decrease errors and errors may result if the pressure responsible for the pain is not fully measured.

The current study findings indicated correlation of 17.7% and 13.5% when the symptomatic area was compared with data (including heel data) obtained with static and dynamic foot pressure tests, respectively. When heel data were excluded, the correlation between the area measured with the second highest foot pressure and the clinical peak pressure region was 51% in static tests and 49% in dynamic tests. In addition, static and dynamic measure-
ments also showed correlation of 41.7% and 31.3%, respectively, after graphic comparison, indicating poor correlation between pedobarographic results and the symptomatic area. On the other hand, correlation in patients with midfoot ulcers associated with Charcot arthropathy was 57% to 100% when determined with both numeric and graphic data. A possible explanation for this finding is that these patients do not feel pain and thus do not exhibit an antalgic gait. On the other hand, all patients with intractable plantar keratosis and metatarsal head callus, as determined by metatarsophalangeal dislocation in rheumatoid arthritis, showed similar correlation. Furthermore, discordance occurred in serial pedobarographic results, even in the same patient (Figure 3).

Quaney et al reported that, of all pedobarographic measurements performed in different areas of the foot, pressure in the heel was the highest. The current study also showed low overall correlation between numeric results and symptomatic areas. Hence, the second highest pressure point except heel data correlated with the area of maximal peak pressure. Exclusion of heel data led to an increase in the degree of correlation, but correlation of 49% to 51% suggested that this information is unlikely to be of diagnostic value. Interpretation of numeric data without the inclusion of heel data seems reasonable.

Despite the general consensus that dynamic measurement accurately reflects foot pressure, the authors’ analyses found dynamic measurement either identical or inferior to static measurement. The decrease in correlation is proposed to arise because walking increases foot pressure by 1.2- to 1.5-fold and promotes an antalgic gait. This proposal must be considered when interpreting the results of the authors’ current and previous studies. It is also possible that the symptomatic area is the area where the pressure exceeds the level of pressure that the skin can withstand rather than the numeric peak pressure area. Skin thickness on different parts of the foot varies, and different frictional forces are imposed on each part. More research on this hypothesis needs to be conducted.

**Limitations**

The current study did not analyze each patient’s walking habits, living environment, Achilles tightness, or lower-extremity alignment, and it remains to be established how much these factors affect measurement. Additional analysis of the correlation of pedobarographic results with the incidence of each foot disorder is needed to address these limitations. One example is comparing pedobarographic results in painful and painless conditions. Because the current patient cohort was small, the categorization of pain on a disease-specific basis in the analyses yielded little statistical significance. Future studies might include a larger number of patients to better correlate pedobarographic results with different conditions associated with inappropriate distribution of pressure over the foot surface.

**Conclusion**

When used to compare numeric pressure values for each part of the foot, pedobarography had a diagnostic correlation of 17.7% for static measurement and 13.5% for dynamic measurement. When determining graphic peak pressure, static measurement showed a correlation of 41.7% and dynamic measurement showed a correlation of 31.3%. Therefore, the diagnostic value of pedobarography appears low.

**References**