



## Correlation between selective pedobarographic and radiographic measures in the assessment of surgically treated CTEV patients

Cerrahi tedavi görmüş DÇA'lı hastaların değerlendirilmesinde selektif pedobarografik ve radyografik ölçümlerin korelasyonu

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**Objectives:** This study aims to assess the correlation between selective pedobarographic and radiographic measures in patients with surgically treated congenital talipes equinovarus (CTEV).

**Patients and methods:** We examined 50 patients [70 feet; 34 girls (68%) and 16 boys (32%); mean age 11.2 months; range 3-30.6 months] surgically treated for CTEV with a mean follow-up of 8.7 years (range 4.3 to 15 years). Patients had radiographic and pedobarographic measurements simultaneously. The right and left feet were assessed separately. The relationship between selective pedobarographs and standing weight-bearing radiographs of the foot was assessed by the Pearson's correlation coefficient and the Spearman's rank correlation coefficient.

**Results:** There were moderate correlations between selective pedobarographic and radiographic measures in surgically treated CTEV patients. The strongest positive correlations were between the right heel rise and right anteroposterior calcaneal-5<sup>th</sup> metatarsal angle ( $r=0.54$ ,  $p=0.001$ ) and, the right anteroposterior talo-1<sup>st</sup> metatarsal angle ( $r=0.48$ ,  $p=0.003$ ). A similar strong positive correlation was observed between lateral tibio-calcaneal angle and left heel rise parameters ( $r=0.42$ ,  $p=0.01$ ).

**Conclusion:** There were moderate correlations between selective pedobarographic and radiographic measures of surgically treated CTEV. However, the pedobarographic measure is a direct measure of the contact force of the foot with the ground and therefore has a more direct functional implication than radiographic measures.

**Key words:** Cerebral palsy; clubfoot; equinus deformity; gait analysis; radiography.

**Amaç:** Bu çalışmada cerrahi tedavi görmüş doğuştan çarpık ayaklı (DÇA) hastalarda, selektif pedobarografik ve radyografik ölçümlerin korelasyonu değerlendirildi.

**Hastalar ve yöntemler:** Cerrahi tedavi görmüş 50 DÇA'lı hasta [70 ayak; 34 kız (%68) ve 16 erkek (%32); ort. yaş 11.2 ay; dağılım 3-30.6 ay] ortalama 8.7 yıllık (dağılım 4.3-15 yıl) bir takiple değerlendirildi. Hastaların radyografik ve pedobarografik ölçümleri eşzamanlı yapıldı. Sağ ve sol ayak ayrı ayrı değerlendirildi. Selektif pedobarografiler ile ve ayakta basarak çekilen ayak radyografileri arasındaki ilişki Pearson korelasyon katsayısı ve Spearman rank korelasyon katsayısı kullanılarak değerlendirildi.

**Bulgular:** Cerrahi tedavi görmüş DÇA'lı hastalarda selektif pedobarografik ve radyografik ölçümler arasında orta düzeyde korelasyon görüldü. En güçlü pozitif korelasyonlar sağ ayaktaki topuk kalkışı ile sağ anteroposterior kalkaneo-5. metatarsal açısı ( $r=0.54$ ,  $p=0.001$ ) ve sağ anteroposterior talo-1. metatarsal açısı arasında bulundu ( $r=0.48$ ,  $p=0.003$ ). Lateral tibio-calcaneal açısı ve sol topuk kalkışı parametreleri arasında da benzer bir güçlü pozitif korelasyon gözlemlendi ( $r=0.42$ ,  $p=0.01$ ).

**Sonuç:** Cerrahi tedavi uygulanmış DÇA'ya ilişkin selektif pedobarografik ve radyografik ölçümler arasında orta düzeyli korelasyonlar vardı. Ancak, ayağın yer ile temas kuvvetinin direkt ölçümünü yansıtmamasından dolayı pedobarografik ölçümler radyografik ölçümlere oranla fonksiyonel çıkarımlar açısından daha direkt bilgi vermektedir.

**Anahtar sözcükler:** Serebral palsi; çarpık ayak; ekin deformitesi; yürüme analizi; radyografi.

Congenital Talipes EquinoVarus (CTEV) is a commonly encountered problem in pediatric orthopedics.<sup>[1]</sup> Whereas the specific etiology remains

unknown, this condition may be related to some viral, genetic, environmental (in utero), and anatomical factors.<sup>[2]</sup> There is no consensus on the neuromuscular

basis of this disorder in the literature.<sup>[3]</sup> Spina bifida, cerebral palsy and other neuromuscular disorders may accompany this disorder in 20% percent of CTEV<sup>[2]</sup> but it is mostly an isolated birth defect and hence considered idiopathic.<sup>[4]</sup> Treatment of these children varies from non-operative methods<sup>[5]</sup> to a variety of surgical techniques.<sup>[6]</sup>

Both radiographic and pedobarographic measurements can be used together or alone in the assessment of surgically treated CTEV. However, to our knowledge there are few studies that have taken these measurements into consideration and correlating the results.<sup>[7,8]</sup> Correlation of clinical results and radiographic parameters had been studied by several authors with varying results.<sup>[9]</sup>

Studies assessing pedobarographic measures for surgically treated CTEV focused mainly on functional outcomes rather than structural (anatomical) success.<sup>[10]</sup>

In planning surgical reconstruction of a deformed clubfoot the surgeon has the option of trying to create normal anatomical alignments as measured by radiographs or to correct the foot so the plantar surface has good floor contact. This present study aimed to assess the correlation between radiographic and selective pedobarographic measures in surgically treated CTEV. We hypothesized that in surgically treated CTEV, radiographic measures of static foot posture and alignment correlate with pedobarographic measures of dynamic foot loading.

## PATIENTS AND METHODS

After obtaining Institutional Review Board (IRB) approval we conducted a retrospective cohort study (case-only) to assess the correlation between radiographic and selected pedobarographic measures of surgically treated CTEV patients.

### Patient sample

This study comprised 50 patients (70 feet) surgically treated for CTEV in our institution between 1984 and 2001. Of the 70 surgically treated CTEV patients, 34 were girls (68%) and 16 were boys (32%). There were 17 right (34%), 13 left (26%), and 20 bilateral (40%) feet. The mean age at the time of surgery was 11.2 months (range 3-30.6 months). All patients had undergone manipulative treatment and serial casting beginning shortly after birth. Correction was not satisfactory in any of the feet, and almost all the patients were treated with the same standard procedure (posteromedial release including lengthening of the Achilles tendon and posterior ankle capsulotomy). Revision surgery was provided to 18 (36%) patients. Specifically, revision surgeries involved tibialis anterior tendon transfer,

lateral closing wedge osteotomies with/without medial opening wedge osteotomies.

All the radiographs were measured by one of the authors and the inter- and intraobserver pedobarographic measurements were done by two experienced engineers from the gait laboratory with at least 10 years of experience as described in the study of Riad et al.<sup>[11]</sup> The average follow-up was 8.7 years (range 4.3-15 years).

### Sample size and power estimations

To determine whether or not one can observe a correlation coefficient ( $r$ ) significantly different from zero (0) in the relationship between pedobarographic and X-ray measures, we utilized a clinically relevant effect size of 0.3 (30%), type I error tolerance of 0.05 (5%), and sample size ( $n=70$ ). With these specifications, we obtained a power ( $1-\beta$ ) of 0.99 (99%), which is a sufficient power to detect a correlation coefficient ( $r$ ) that is significantly different from zero, correlating heel rise to the radiographic measures of CTEV.

### X-ray

The radiographic assessment includes measurements and angles of both the Anterior-posterior (AP) and lateral standing views of the foot respectively. Anterior-posterior view angles were; (i) Calcaneal-5<sup>th</sup> metatarsal angle: This is the angle formed between a line along the lateral border of the calcaneus and second line along the lateral border of the 5<sup>th</sup> metatarsal. (ii) Calcaneal-1<sup>st</sup> metatarsal angle: It is the angle between a line along the mid axis of the calcaneus and the line along mid axis of the 1<sup>st</sup> metatarsal. (iii) Talo-calcaneal angle (Kite's angle): It is the angle between the mid axis of the talus and the line along the mid axis of the calcaneus.

Lateral view angles were; (i) calcaneal pitch angle (or calcaneus inclination angle): This is the angle between the inferior surface of the calcaneus and the line parallel to the floor (the weight bearing surface of the foot). (ii) Talo-1<sup>st</sup> metatarsal angle (Meary's angle): This is the angle between the line midpoint of the 1<sup>st</sup> metatarsal and the midtalus axis. This angle varies in cavus or rocker bottom deformities of the foot. (iii) Tibial-calcaneal angle: This is the angle between the mid diaphysis of the tibia and the inferior surface of the calcaneus. This is the measurement of equinus or calcaneus deformities at the level of ankle joint. (iv) Calcaneal-1<sup>st</sup> metatarsal angle (Hipp's angle) is the angle formed between the mid axis of the 1<sup>st</sup> metatarsal and the mid axis of the calcaneus. (v) Talo-calcaneal angle is the angle between the mid axis of the talus and mid axis of the calcaneus.

### Pedobarograph

Pedobarograph simply refers to the measure of the foot pressure as it comes in contact with the floor, and includes several parameters. In our study we selected 'Heel-Rise' parameter to correlate with X-ray measures. The time to heel rise is a measure of how quickly the heel elevates.

Pedobarographic measurements were obtained using the Tekscan High-Resolution Pressure Assessment System. The system consists of a 61x65 cm<sup>2</sup> pressure sensitive floor mat containing a grid of 87 rows and 96 columns of pressure sensing cells recording at a rate of 60 Hz.

### Statistical analysis

We first examined the continuous data for normality assumption. Frequency and percentage were used to summarize the categorical data while mean and range were used to summarize the continuous data. To test the specific hypothesis we used Pearson correlation coefficient for normally distributed variables and Spearman rank correlation coefficient for distribution-free or non-normally distributed data. We specified the magnitude of the correlation using: (i) weak correlation=0.00-0.39, (ii) moderate correlation=0.40-0.79 and (iii) strong correlation=0.80-1.00. All tests were two-tailed, with 0.05 as the significance level. The analysis was performed using STATA statistical software, version 10.0 (StataCorp, College Station, TX, USA).

## RESULTS

The pedobarographic measures of the surgically treated CTEV had a high variation in all measures with no strong correlations that would be predictive for individual cases.

### Heel rise

The time for right and left heel rise pedobarographic measures was not different from normal children. There was a statistically significant positive correlation between left heel-rise and left lateral tibio-calcaneal angle ( $r=0.42$ ,  $p=0.01$ ). A statistically significant positive correlation was also observed with left heel rise and left AP calcaneal-5<sup>th</sup> metatarsal angle ( $r=0.37$ ,  $p=0.03$ ). Both the right AP talo-1<sup>st</sup> metatarsal angle ( $r=0.48$ ,  $p=0.003$ ) and right AP calcaneal-5<sup>th</sup> metatarsal angle ( $r=0.54$ ,  $p=0.001$ ) showed a moderate positive correlation with the right heel rise (However there were no significant correlations between heel rise and the rest of the radiographic measures,  $p>0.05$ ).

## DISCUSSION

The preferred method to assess the outcome of treated CTEV remains to be determined. We

retrospectively assessed 70 feet (50 patients) with CTEV for the relationship between pedobarographic and radiographic measures. We postulated that in the surgically treated CTEV, selective pedobarographic parameter (heel-rise) correlates with the radiographic measures of the foot. In this study, we elected to evaluate the right and left sides separately, since this gives us two groups with relatively similar means and very wide ranges. Since the goal of the assessment was to determine strong correlations, an anatomical change in the bone alignment should have generated an improvement in the foot to floor contact leading to a statistical correlation such as  $r>0.75$  on left and right feet.

There are several important findings in this study. Primarily, there were no strong correlations between pedobarographic and radiographic measures of the surgically treated CTEV, based on the follow-up outcome assessment. Secondly, the most potent positive correlations were between the right heel rise and right AP calcaneal-5<sup>th</sup> metatarsal angle as well as right AP talo-1<sup>st</sup> metatarsal angle.

Early clinicians tended to focus on radiographic measures such as Kite's angle or Hipp's angle. However, Ponsetti tended to ignore radiographic measures in favor of visual foot appearance. Current clinicians working in environments with gait laboratories tend to prefer pedobarograph because it is an objective measure of how the foot interacts with the floor. The goal of treatment of the deformed foot is to have a foot which supports weight without high-pressure areas on the sole of the foot and to provide a lever arm on which the plantar flexors can act. Because radiographs are also widely used especially when gait facilities are not available, there should be some understanding of how individual measurement areas between these two systems correlate.

Some of the correlations observed in this study do represent consistent anatomical and functional relations. The time to heel rise is one of the measures of ankle equinus and the correlation to AP calcaneal-5<sup>th</sup> metatarsal angle support the concept that increased forefoot adduction is correlated with increased ankle equinus.

Despite the strength of this study, there are some limitations. First, like most retrospective studies there is a tendency of introducing information and selection bias into our findings. However, this is unlikely since we performed reliability check using data source to verify the information used in this study. Secondly, lack of preoperative pedobarographic measures limited our ability to compare the outcomes of treatment

in assessing foot function before and after surgery. Finally, this study correlates only one pedobarographic measure with X-ray parameters and needs to correlate all pedobarographic measures with all X-ray parameters. Therefore the lack of a significant correlation does not necessarily imply absence of a relationship. However, it does imply absence of a significant relationship, given the sufficient power in this study. Consequently, the results of this study with respect to relationship between selected pedobarographic and radiographic measures of the surgically treated CTEV should be interpreted with caution.

Whereas radiographs assess foot anatomy and pedobarographs assesses foot contact with the ground implying functionality, a strong correlation of these parameters should not be expected. This study clearly shows that surgical planning to correct radiographic foot anatomy does not lead in any consistent manner to a desired outcome of the foot-ground contact as measured by pedobarography. We recommend further analysis including prospective designs with other populations and pathologies to understand the correlation between pedobarographic and radiographic measures related to foot deformities.

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