# CHILDREN'S PLANTAR PRESSURE DISTRIBUTION MEASUREMENTS: INFLUENCE OF FOOTWEAR

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**INTRODUCTION:** Several significant studies (Aharonson et al., 1989; Orlin et al., 1990; Hennig & Rosenbaum, 1991; Pisciotta et al., 1994) have increased interest in plantar pressure distribution parameters in childhood. All over the world the gait labs, with their ongoing research studies on gait kinetics, are beginning to look for pressure distribution values, as for example Bontrager et al. (1997).

More than a hundred years ago, Marey in 1886 and Beeley in 1882 developed plantar pressure measurement techniques. These techniques have continued to be developed, and at present there are measurement systems based on such different principles as footprints, optical, acoustical, pneumatic, hydraulic, inductive, piezoelectric, capacitive and resistive. (Borges Machado, 1994)

With regard to plantar pressure distribution it must be remembered that there are different ways to measure this parameter. Depending on the characteristics of the measurement systems, data can be obtained for subjects either barefoot or in-shoe. This study focused on the use of a measurement system that obtains pressure distribution data in-shoe. There are two possibilities. First, sensors can be placed on interesting anatomical points on the plantar surface of the foot. Second, insoles can be placed inside the shoe, covering the total plantar surface of the foot. Both measurement systems have been commercially available for many years and are most often used by groups interested in in-shoe measurements. A very important aspect is the localization of points or regions of interest. When sensors are used, they must be placed correctly at the anatomical points on the *Regio plantaris, the* plantar surface of the foot that is of interest. When working with insoles, information can be obtained about the role of the plantar surface of the foot; therefore, after data collection, the regions of interest must be defined.

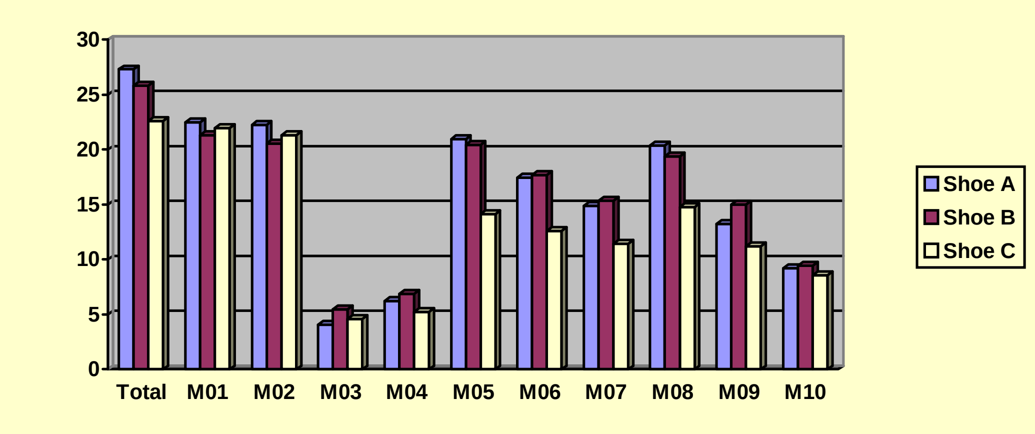
Looking at normal foot-ground pressure parameters, Aharonson et al. (1980) examined 18 boys and 28 girls between the ages of 4 and 6 years using an optical footprint measuring instrument. Using a pedobarograph that utilizes pressure sensors within a platform, Orlin, Pierrynowski and Robertson (1990) collected static barefoot data from a total of 34 children in different age categories between 1.5 and 10 years. Comparing the pressure distribution in adults with children, Hennig and Rosenbaum (1991) used a capacitive pressure distribution system. They conducted their study with 15 children ranging in age between 14 and 32 months and compared the results with a group of 111 adults. The findings reveal that the absolute values of the maximal pressure under the specified foot regions during walking are considerably higher in the adults than in the children. This is caused by a softer structure of the infant foot and by a 1.5 times higher body-weight to foot-contact region ratio in the adults. The relative load increases with age under the third and fifth metatarsal heads and decreases under the first metatarsal head. With a sample of 168 infants, Pisciotta et al. (1994) established a normative database to provide an accurate basis for comparison with other research populations. The children were classified in age intervals between 1-2 years, 3-4 years and 4-5 years. They stated that a steady progression seems to occur in the foot pressure regions, timings and magnitudes until approximately age 4, when the pattern appears similar to the foot pressure patterns of normal adults, but with smaller magnitudes of peak pressure in the regions.

Most of the studies using plantar pressure distribution parameters were done during gait. In the literature we found two recent studies realized during daily activities. First, the study by Lundeen et al. (1994) comparing adults' level walking with other ambulatory activities. Second, the study by Rozema et al. (1996) investigated the implications of in-shoe plantar pressure for therapeutic footwear design.

In this study the main goal was to collect normative data on plantar pressure distribution parameters during daily activities and to look for differences due to different kinds of footwear.

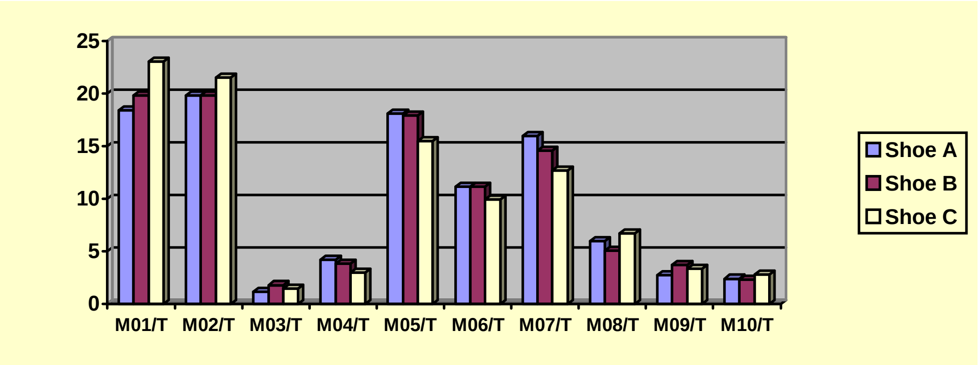
**METHODS AND PROCEDURES:** Subjects of the study were thirty-eight children (boys and girls) with a mean age of 9.56 years who participated as volunteers. After some anthropometric measurements, standing footprints were made for each foot. Subjects were instructed to distribute their weight equally on both feet. Data were collected using a Berkemann Footprint-Mat (Berkemann, Hamburg, Germany). To look at the parameters in the different shoe conditions, we used an insole system, pedar System (Novel, Munich, Germany). The insoles have capacitance-based sensors, each insole has eight-four sensors. An insole in European sizes 34-35 was used. The sampled frequency was 50 Hz. Data were collected using three different kind of shoes: nubuk casual shoe, a leather casual shoe and a children's sport shoe. Subjects had a trial period to get used to wearing the shoes. The tasks to be performed were: standing with the whole body weight divided equally between both feet, walking at a normal walking pace, running, a slalom task and walking up and down stairs. For the tasks of walking, running and slalom we marked out a walkway of 10 m, within which 6 meters were recorded. The subjects were asked to walk down the walkway at a normal pace. After the initial processing of the collected data, the foot was divided into 10 regions of interest. For this we used an application of the Novel Ortho Program, the AutomaskEvaluation. In our case we chose the PRC Mask Option. The foot regions were the following: Medial-Heel (M01), Lateral-Heel (M02), Medial-Midfoot (M03), Lateral-Midfoot (M04), *Os Metatarsale I (M05)*, Os *Metatarsale II (M06)*, Os Metatarsale III-V (M07), *Hallux (M08)*, *Digitus II (M09)*, *Digitii III-V (M10)*. Anthropometric data on the foot were also calculated. Here we present the results for walking, running and the slalom tasks. Data were analyzed using the ANOVA procedure and the Bonferroni method of multiple comparisons using SAS software.

**RESULTS**: After calculation of descriptive statistical data, an ANOVA procedure and the Bonferroni method of multiple comparisons to control the experiment-wise error rate ($\alpha$) to 0.05 were performed. Significant differences between the shoes for all tasks were considered for a Type III p-value less than 0.0001 associated with a Bonferroni t-test. Looking at the Graphic 1 with the values for peak pressure ($N/cm^2$) for the total foot as well for all foot regions (M01 to M10), the most statistically significant differences among all three shoes for the walking task were observed for the *Os Metatarsale* I region (M05), the *Os Metatarsale* II region (M06) and for the Hallux (M08). Analyzing the peak pressure values for the other two tasks, the most significant differences were found during running for the *Os Metatarsale I*, *Os Metatarsale II* and Hallux regions as well. Looking at the values for the slalom task the most significant differences were found for the *Os Metatarsale I* region, *Os Metatarsale III-V* region and for the Hallux region.




**Graphic 1: Peak Pressure (N/cm$^2$) for all foot regions during walking**

Relative load values were also calculated using the impulse under a foot region divided by the sum of all other foot regions. Looking at this relative load percentage values for walking (Graphic 2) we observed for the Medial and Lateral- Heel regions values around 19 % for shoe A and B and about 22 % for shoe C. For the *Os Metatarsale I* region values about 18 % were found for shoe A and B and 15 % for shoe C. Analyzing this parameter for the running task the largest values for all three shoes were found in the *Os Metatarsale I* region, with values about 21 %. Looking at the values for the slalom task we also found the largest values in the *Os Metatarsale I* region (19% for shoe A, 20% for shoe B and 18% for shoe C).




**Graphic 2: Relative Load (%) for all foot regions during walking**

**CONCLUSIONS:** Looking at the results of the present work, we confirm the necessity and importance of dividing the foot into different regions, as the several anatomical regions of the foot are loaded unequally. It seems clear that the foot is loaded differently in performing different movements. The most important aspect in

this study, however, was the footwear influence on the plantar pressure distribution. Although in all tasks statistically significant differences were found between the shoes for some regions of the foot, more efforts to specifically study children's shoe mechanical aspects are needed. Our initial goal of starting to look at this aspect during childhood has been achieved. Future studies are planned to study a larger population and analyze footwear mechanics more closely.
Plantar pressure distribution in children's feet is an important factor that should be studied. Footwear should fit and protect children's feet and be adequate to meet the demands made by different kinds of movement.
Today special footwear for almost every sport activity are commercially available for adults. We suggest that plantar pressure distribution aspects as well as other biomechanical parameters should also be used to develop more specific footwear constructions for children.

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