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Original Research Article

Static Pedobarographic Profiles in Normal School Aged Saudi Arabian Children

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ABSTRACT

Background: The developing foot changes structurally to fulfill locomotion requirement. These changes are necessary for physiological development of children's foot and posture. The aim of the study was to describe the static foot profile of the Saudi Arabian school aged children and its correlation to children ages and Body Mass Index.
Design/Methods: A single-group exploratory design using correlation and regression was used to identify the relationships. One hundred healthy school aged Saudi Arabian children were recruited from numerous local schools in Alkharj Area. Their ages ranged from 6 to 12 years. Foot geometry (foot length, foot width and foot form index) and percentage of body weight distribution on five anatomical foot areas (heal, midfoot, metatarsal heads, big toe and the lateral 4 toes) were evaluated using Tekscan HR Mat™ pressure measurement system.
Results: Statistically significant correlation of static foot pressure distribution (% of body weight) with children age (p-value <0.05) with exception of mid foot area was recorded. Also, body mass index was significantly related to static foot pressure distribution. Both children age and BMI was statistically significant predictor of static foot pressure distribution.
Conclusion: This study provides the clinician with a potentially useful database of static planter pedobarography for Saudi children that have a valuable comparative value when assessing foot abnormalities.

Ker words: Static pedobarography, Foot pressure, Planter loading characteristics.

INTRODUCTION

In the childhood stages, the musculoskeletal system exposes to spectacular development of skeletal and muscular structures. It subjects to compressive and tensile stresses, those are important for normal development of the bones and muscles morphology for loading requirements in next developmental stages. [1] So, children's development of normal posture and gait pattern wouldn't be achieved without normal development of their feet.

The body gets in contact with the ground through the foot. So it is necessary for development of the musculoskeletal system. The developing foot changes structurally to fulfill locomotion requirement. These changes are necessary for physiological development of the foot. [2]

However, the foot development may reveal wide differences. So, differentiation between the normal and abnormal development is a difficult task.[3,4]

Pedobarography becomes more widely used in assessment of children with foot disorders. Serial measurements could be conducted in the clinical practices to follow and monitor foot pathology at different time intervals and evaluation of the treatment effects. [5-8] Research proposals and protocols could be developed for acquisition of pedobarographs and evaluation of foot profile. [9]

The foot profiles changes overtime. So, it is age related, particularly when the foot develops from the flatfoot pattern in the early stages of development to matured curvilinear pattern in late childhood. So the provision of normative database with age correlation is too much necessary to set as standards for comparison with peer children with foot disorders. [10]

Considering the Body Mass Index (BMI) and foot function, it is proposed that the tissues of organisms cannot maintain its morphological characteristic as the body mass index increases and that interfere with locomotive functions in large and small organisms. [11]

A large body of evidence proved that increment of BMI as having a negative effect on the development of the lower limbs as well as the pathologic entities. Higher foot plantar pressures in the heel, midfoot and forefoot may increase the risk of lower extremity pathological changes. [12]

However, no previous studies were conducted to identify the normative data regarding the anthropometric measurements. Specifically, the pedobarographic profile among the normally developing Saudi Arabian children. Provision of normative data of the foot pressure distribution of Saudi Arabian children could be used by orthopedists, orthopedic surgeons, neuropediatricians, physical therapists and other health care professionals for early prediction of foot and postural abnormalities and abnormal coping strategies that may have harmful effects on their development. So, this study was conducted to describe the foot pressure profiles of normal children across different ages of the young Saudi Arabian children, identification of age-related differences in foot pressure patterns and find out the relation of the foot pressure profile to the body mass index among Saudi Arabian children.

MATERIALS AND METHODS

Subjects

A sample of 100 healthy school aged Saudi Arabian children from numerous local schools in Alkharj Area were assessed for eligibility, 64 children were appropriately and conveniently selected to participate in the present study. Parents or legal guardians of all children agreed to participate in the study and informed consents were obtained and standards of local ethics were followed. Children ages ranged from 6 to 12 years. Children were eligible for the study if they did not have any foot or lower limb pathology or any underlying condition. Children with orthopedic or neurological disorders will be excluded. Children who didn't reveal abnormal findings were included. Otherwise they were asked to do further orthopedic assessment by a pediatric orthopedist for further clarification.

Instrumentation and procedures

The Tekscan HR Mat™ pressure measurement system (South Boston, MA) and Research Foot Module were used to collect pedobarography data. [13] This system has previously known to have moderate to good reliability for the assessment of plantar pressures in healthy children (Interclass Correlation Coefficients ranged from 0.58 to 0.99). [14]

It provides static and dynamic barefoot pressure and force measurements using a low profile (height 0.225 inch or 0.57 cm), high resolution floor mat. The system provides for plantar pressure screening, foot function assessment, documentation, and education. Its high resolution sensor (4 sensors/cm2 or 5 mm spatial resolution) makes it especially useful in the evaluation of children. The size of sensing area 442mm x 488mm and contained 8352 resistive sensing elements. Data were collected at 60 Hz and calibration was done using each child's body weight prior to data collection. Prior to measurement, children were familiarized with the testing procedure and details were explained to them.

The pedobarography protocol involved evaluation of static footprints and foot loading parameters during stance phase of walking cycle. For the static test, each child was asked to stand barefoot in bipedal stance on the mat, with their arms relaxed by their sides, they were instructed to look forward at a fixed point for 20 second. Three trials of the static test were registered for each child and the outcome measures of the valid test were used for further analysis. The foot length (FL) and the foot width of the midfoot area (FW) were evaluated to calculate a foot form index (FFI) (defined as midfoot width divided by length, in percent). Moreover, percentages of body weight distribution over five anatomical areas of the foot; heal, midfoot, metatarsal heads, big toe and the lateral 4 toes (figure 1).

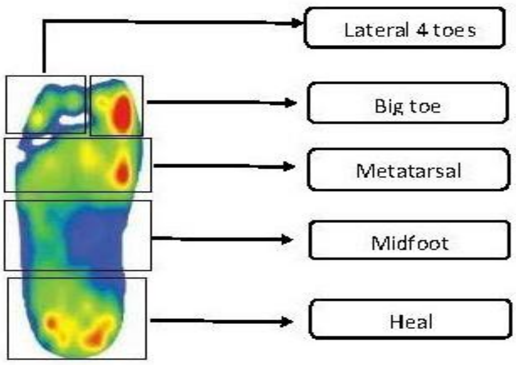

Figure 1: Foot Masks

Statistical analysis

Descriptive statistics (mean and standard deviation) were computed for all data. Intraclass Correlation Coefficient (ICC) was used to measure the intra-rater reliability of the measurements for the first 10 children. Spearman's correlation coefficient; α=0.05 two-tailed was used to determine the relationship between the peak planter pressure and foot profile and children's age and body mass index. The strength of the relation was interpreted on the following basis, little or no relationship if r value = 0.00 to 0.25, fair relationship when r value =0.25 to 0.50, moderate to good relationship if r = 0.50 to 0.75 and good to excellent if r > 0.75. [15] Simple linear regressions will be used to quantify the strength of the relationships.

RESULTS

Participant characteristics

A total of 100 children were assessed for eligibility, 64 children were appropriately selected to participate in this study. Their mean ages were 9.92 ± 1.79 years, weights were 30.24 ± 8.68 kg, heights were 129.59 ± 9.13 cm and BMI was 17.75 ± 3.38 as shown in table 1.

Foot Geometry

Two way mixed interclass correlation reliability test was conducted, estimates of the Interclass Correlation Coefficient (ICCs) of two measurement for the first 10 children indicated excellent agreements between raters (ICCs was 0.935, 0.878, 0.883, 0.985 and 0.928 for the heal, midfoot, metatarsal heads, big toe and the lateral 4 toes respectively). So, the measurements were very consistent.

Table 1: Demographic characteristics of the participants

	Mean ± SD	Range
Age (yrs)	9.92 ± 1.79	(6 – 12)
Weight (kg)	30.24 ± 8.68	(19.5 – 54)
Height (cm)	129.59 ± 9.13	(110.5 – 147)
BMI	17.75 ± 3.38	(13.64 – 26.53)
SD: standard deviation, yrs: years, kg: kilogram, cm: centimeter		

Foot length and foot width increased with increasing age, ranging from 18 – 25.80 cm for foot length and 7 – 9.4 cm for foot width. The mean foot length and foot width was 21.54 ± 2.37 and 8.36 ± 0.69 respectively. Foot Form Index mean value was 0.39 ± 0.05 ranged from 0.30 - 0.49. Statistically significant ($p < 0.05$) fair positive relationship between children ages and foot length and foot width were recorded (0.25 < correlation coefficient > 0.50). But, statistically non-significant relation between foot length and foot width with BMI was reported ($p > 0.05$). Additionally, the foot form index outcomes showed statistically non-significant relationship with both children ages and BMI as demonstrated in table 2.

Table 2: Foot Geometry and its correlation to ages and BMI

Foot Geometry	Mean ± SD	Correlation with age		Correlation with BMI	
		CC	P - Value	CC	P - Value
Foot length (cm)	21.54 ± 2.37	0.350	0.005	0.058	0.648
Foot width (cm)	8.36 ± 0.69	0.412	0.001	- 0.045	0.727
Foot Form Index	0.39 ± 0.05	- 0.095	0.456	-0.076	0.550
SD: standard deviation, CC: correlation coefficient					

Estimates of linear regression model indicated that age is a statistically significant predictor of foot length ($p = 0.019$) and foot width ($p = 0.002$) with 0.38 cm increase in foot length and 0.15 cm increase in foot width each year increase in children age.

Static pedobarographic profile during standing

Table 3: Static pedobarographic profile and its relation to children ages and BMI

foot areas	Pressure % of BW Mean ± SD	Correlation with age		Correlation with BMI	
		CC	P - Value	CC	P - Value
Heal	25.93 ± 2.52	0.315	0.011	0.456	0.001
Mid foot	17.53 ± 2.49	0.096	0.452	0.498	0.000
Metatarsal heads	13.48 ± 1.70	0.324	0.009	0.256	0.041
Big toe	1.69 ± 0.56	0.266	0.033	0.289	0.020
Lateral 4 toes	0.52 ± 0.20	0.328	0.008	0.324	0.009
BW: Body Weight, SD: standard deviation, CC: correlation coefficient					

As demonstrated in table 3; statistically significant ($p < 0.05$) fair positive correlation between children ages and pressure distribution over the heal, metatarsal heads, big toe, and the lateral 4 toes (0.25 < correlation coefficient > 0.50) and pressure distribution over the midfoot was not significantly ($p > 0.05$) related to children ages (figure 2). Also, statistically significant ($p < 0.05$) fair positive correlation was indicated between BMI and pressure distribution on the heal, midfoot, metatarsal heads, big toe and the lateral four toes (0.25 < correlation coefficient > 0.50) (figure 3).

As demonstrated in table 4, estimates of linear regression model revealed that children ages and BMI are statistically significant predictors for static pressure distribution on all foot masks ($p < 0.05$). For each year increase in children age between 6 and 12 years, the pressure distribution will increase by 0.5 %, 0.3%, 0.08 % and 0.4 % of body weight on the heal, metatarsal heads, big toe and the lateral 4 toes respectively. But, children age was not found to be a statistically significant predictor for pressure distribution on the mid foot.

Also, the static foot pressure distribution increased by 0.34%, 0.36%, 0.13%, 0.05% and 0.02% of body weight for the heal, midfoot, metatarsal heads, big toe and the lateral 4 toes respectively for each unit increase in BMI.

Table 4: The association of static foot pressure distribution with children age and BMI

	Children age			BMI		
	β	CI	P-value	β	CI	P-value
Heal	0.494	(0.159 - 0.829)	0.004	0.341	(0.172 – 0.510)	0.001
Mid foot	0.109	(-0.243 - 0.460)	0.538	0.367	(0.205 – 0.529)	0.000
MT heads	0.326	(0.100 - 0.551)	0.005	0.129	(0.005 – 0.252)	0.041
Big toe	0.084	(0.008 - 0.161)	0.031	0.048	(0.008 – 0.088)	0.020
Lateral 4 toes	0.039	(0.012 - 0.065)	0.005	0.019	(0.005 – 0.034)	0.009
BMI: body mass index, β: regression coefficient, CI: confidence interval, MT: metatarsal heads						

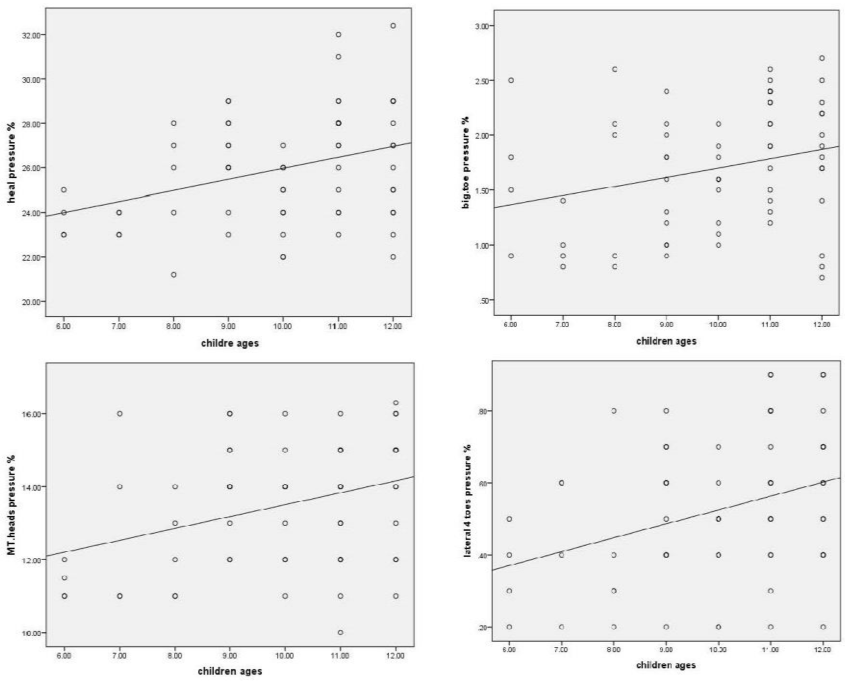

Figure 2: Relationship of children ages and percentages of static foot pressure distribution

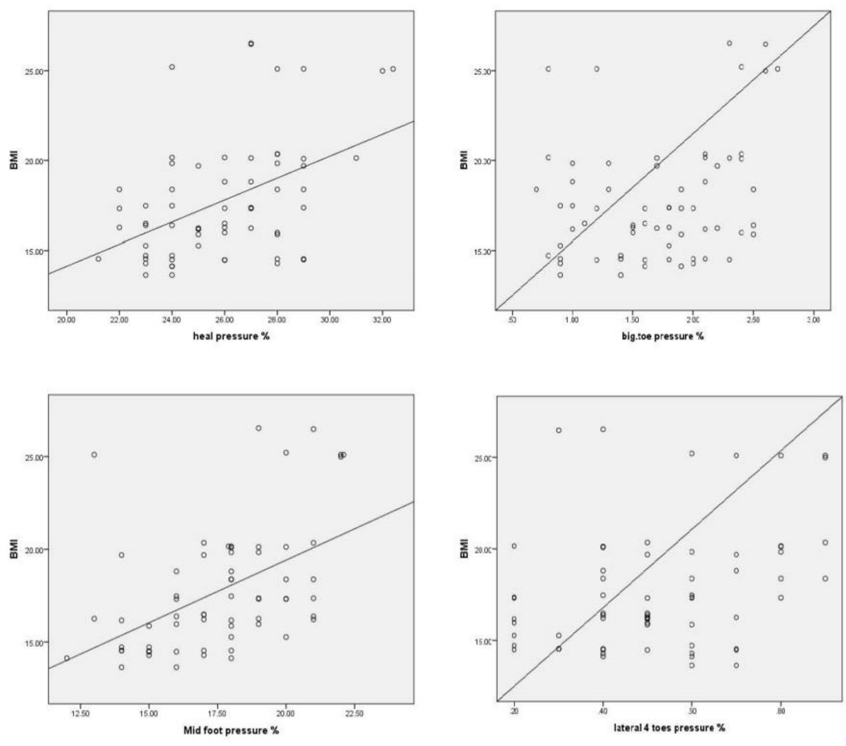

Figure 3: Relationship of BMI and percentages of static foot pressure distribution

DISCUSSION

The foot pressure as well as the foot geometry rapidly changes as long as the children grow and mature. However, no or rare studies regarding foot geometry and planter loading characteristics of the Saudi Arabian children might be found. Therefore, the purpose of this study was to measure the planter loading characteristics and establish the static pedobarographic profile of the foot of the Saudi Arabian school aged children and find out its relation to their ages and body mass index.

It has been shown in the previous studies that foot length and foot width enlarges with increasing age among the children population. [16, 17] Conversely, the foot form index which describes the foot width divided by the foot length declines with increasing age and become more similar to that of that of the adults as they grow and develop because the rate of growth of foot length is predominantly higher than the rate of growth of foot width. [18] In addition, previous studies revealed significantly higher values of body mass index being one of the factors that has an impact of foot morphology during childhood development. [19,20] Children with high body mass index displayed significant greater foot dimensions than their peers with lower body mass index. [21]

In the present study, the differences regarding foot length and foot width were as evident as predicted on the basis of our knowledge from previous researches and children age was found to a significant predictor of both foot length and foot width. The results indicated an increase in foot length and foot width as the age progresses with prevalent increase in foot length in relation to foot width. In contrast, non-significant relation between the body mass index and foot geometry was reported. These findings could be attributed to the musculoskeletal changes and the proportional increase in foot dimensions with increasing age. Whereas, children with high body mass index develops no changes in the skeletal hights. [22]

Regarding to the planter pressure distribution, it was examined during standing and the planter pressure (% of body weight) was found to be greatest under heal followed by metatarsal head, midfoot then the big toe. While the least pressure was recorded under the lateral four toes. Furthermore, planter pressure distribution was significantly relate to children age, and found to increase with age progression with exception of pressure under the midfoot. Likewise, significant association of the planter loading with body mass index was revealed in the outcomes of the current study.

The planter loading characteristics was expected to increase once again as the children grow and gain more weight and height. This hypothesis was proven by the results of the current study on the planter pressure distribution during standing on heal, metatarsal heads, big toe, and the lateral four toes. But, the planter pressure distributed to the midfoot was not found to consistently increase as the age increases. It might be related to the development and alleviation of flatness of the longitudinal arch of the feet that develops and raise with age progression. [17] This outcome were basically in agreement with Kellis, 2001 and Bosh et al., 2009 who reported approximately similar findings in their recent studies. [23,24] Also, Hills et al., 2001 reported a link between the force of mechanical loading or pressure under the foot and body mass index. [25] Conversely, Phethean and Nester, 2012 reported weak degrees of association ($r > 0.48$, $p < 0.05$) between body mass index and plantar loading, they explained their by the fact that children weight increases with a proportional increase in the dimensions and contact area of the foot. [26] Unlikely, we assumed that children with high body mass index gains more weight and develop no or little changes in the skeletal heights.

Consequently, the foot dimensions and pressure or contact areas develop no or little changes. So, the planter loading might be increased over a small foot contact areas. This concurs with the results of previous researches concluded that foot areas may display high planter pressure in obese children with high body mass index though they may develop an increase in foot dimensions and foot contact area. [27,28]

Possible limitation to be mentioned, being a single group exploratory design; the findings might be used initially to describe and document the outcome measures instead of drawing final conclusion about them. In the present study, schools Saudi Arabian were examined to establish the static pedobarographic profile in different subjects. Incoming studies could examine the same measure in a cohort or cross sectional studies to monitor and clearly identify changes of foot geometry and planter loading during growth and development within the same subjects. Also, potential bias could arise from the small sample size. It is recommended to considerably recruiting larger sample in the next researches.

In spite of the previously mentioned limitations of this study, it has some strength, including the use of high sampling frequency (60 Hz) pressure mat for assessment that allowed high resolution and inspection of the anatomical landmarks of children foot. In addition, data was collected and accurately represented from consistent and objective and reliable assessment by the same subject.

Conclusively, the obtained results have indicated an evident age and body mass index related changes of the static pedobarographic profile in Saudi children aged from 6-12 years. Planter loading database of normal children might be beneficial for comparison while assessing foot abnormalities.

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