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# Postural Sway Parameters and Gait Symmetry in Preschool Children: Cross-sectional study

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**Abstract —** The most important function of posture is to ensure the maintenance of control during the start and the continuation of human movement, moreover, posture serves as a reference for the production of precise movements. The aim of this study was to relate the postural sway parameters and gait symmetry in preschool children.This study is a cross-sectional study, conducted in 49 children with a mean age of 4.65 ± 0.44 years. Initially, height and body mass of children were measured using anthropometric scales. Next, an electronic baropodometer was used to evaluate the distribution of dynamic plantar pressure (gait) and stabilometry (balance).A Student t test or Mann-Whitney test for comparing two groups was used. To correlate variables, a Pearson's correlation or Spearman's correlation coefficient was used. The stabilometric parameters showed no significant difference between an eyes open test and eyes closed test in preschool child. We found a moderate relationship between axis inclination and cadence symmetry (R=0.40;p=0.007). Postural sway parameters have relationship cadence symmetry of the gait in preschool children.

Keywords: balance, child development, children, gait

## Introduction

Static balance is the ability to control an upright posture for maintaining orientation and stability[1].The most important function of posture is to ensure the maintenance of this control, during the start and the continuation of human movement; moreover, posture serves as a reference for the production of precise movements[2].

The functional development of a child's balance system begins to have postural control strategies similar to adults around the age of 7–8 years[3]. Before that age, the oscillation speed and the area of the ellipse, in a stabilometric assessment, are higher in children, indicating incomplete development of the integration of the vestibular and the central nervous systems[4].Thus an assessment of the balance during childhood is essential, as possible changes may interfere with the general and daily conduct of the child and even in school performance.

Body control in the static posture is important for the performance of functional activities that put the body in motion[5].One of the most challenging activities for balance is the gait[6].Postural and gait control are interdependent at different levels of the central nervous system, but there is an integration of this central control as these two motor functions share some common principles of spatial organization[7].

Problems in the static postural and gait control in hemiparetic patients share some common neural origins. The asymmetry of oscillations of the center of pressure (CoP) during bipedal posture affects the performance of the gait, increasing the time and effort required to move the weight toward the affected limb. The degree of postural asymmetry measured by stabilometry is associated with the degree of gait disturbance variable[8,9].

It is possible to find some studies in the literature about postural control in development children growth[4,10,11],but the relationship between this control and the gait is rarely studied in this population[12]. However, a study of children with hemipareticcerebral palsy described the importance of body control in the static position for the performance of functional activities that put the body in motion[5].Given this context, this study aimed to correlate the postural sway parameters and symmetry of gait parameters in preschool children, an age when the postural control system is under development.

## Methods

This is a cross-sectional study to correlate the postural sway parameters and symmetry of gait parameters of 49 children enrolled in a philanthropic day care center. The means of age, height, mass, and body mass index (BMI) are shown in Table 1.

Table 1
*Anthropometric characteristics of children of preschool age (mean, standard deviation, minimum and maximum values).*

| **Parameters** | | |
|---|---|---|
| | **Mean ± SD** | **Minimum–maximum value** |
| Age (years) | 4.65±0.44 | 4.00 - 5.75 |
| Height (cm) | 106.25±4.64 | 98.00 – 117.00 |
| Body mass (kg) | 17.27±2.37 | 13.00 – 24.00 |
| BMI | 15.25±1.59 | 12.39 – 19.21 |

Data expressed as mean ± standard deviation. BMI, body mass index; SD, standard deviation.

The sample was selected by convenience. Inclusion criteria were children between 4 and 6 years old, regularly enrolled in a philanthropic day care center. Exclusion criteria were the presence of pathologies on the feet or other disorders that lead to potential gait limitations, such as fracture of any body part that may have interfered with the development of posture, genetic diseases or musculoskeletal disorders or skeletal neuromuscular or degenerative diseases.

This study was approved by the Research Ethics Committee of the Federal University of Ceará, under the protocol number 089/11 and was conducted in accordance with Resolution 466/12 of the National Health Council. Those legally responsible agreed on the participation of the children by signing a free and informed consent.

This clinical research was conducted at the Human Motion Analysis Laboratory, Department of Physical Therapy, Public University, from September 2011 to April 2012, in a prepared environment so that the children felt comfortable and spontaneous during evaluations. All children remained barefoot, with minimal clothing, to allow a good view of their positions.

Initially, the height (m) and body weight (kg) of the children were measured using an anthropometric scale (Welmy, Santa Bárbarad'Oeste, SP, Brazil), with an accuracy to 100g and 0.5 cm. BMI was calculated by dividing weight by height squared.

Then they were placed in an electronic baropodometer (DiagnosticSupport-DIASU, Rome, Italy), consisting of a modular platform with 4,800 active resistive sensors in an array of 320 cm for measuring the distribution of dynamic plant pressure and stabilometry.

The analysis was performed using the Milletrix software that provides a description and quantification of the results presented using a color scale–proportional to the pressure exerted on a certain area of the detector–where brown shades represent lower pressures and red shades represent higher pressures[13].

The distribution of dynamic plant pressure data were collected during gait with free speed in a baropodometer runway. The route was completed when the researcher had identified four-to-six steps of the child had been collected by the software, from the first contact until the end of the walk. The numerical values evaluated were as follows: surface contact area ($cm^2$), load (kg) maximum pressure ($g/cm^2$), average pressure ($g/cm^2$), contact time (s), step (cm), cadence (steps per minute). All parameters were evaluated for both feet.

The stabilometric review assessed balance—with the individual in the standing position on the platform, natural, and relaxed, staring at the horizon, arms at both sides and feet slightly apart—and this protocol was evaluated for 30 seconds. Before each test, to restore physiological symmetry the patient was asked to inhale and exhale (once) to relax the kyphosis and lordosis curves and swallow (once) as a postural "reset."Individuals were evaluated with eyes open and then with eyes closed for the analysis of oscillations in the anteroposterior and latero-lateral plans. The parameters evaluated were surface of the ellipse ($mm^2$), eccentricity index (%), length of oscillation (mm), axial inclination (o), average speed (mm/s), and average speed (mm/s) in the anteroposterior (AP) and lateral-side (LL) axis.

The asymmetries observed during gait assessment were calculated by gait symmetry angle [45-arcotan(X left/right X)-180)/90) × 100%](14).

Our sample comprised 49 children. The power t test was calculated based on the Chester & Calhoun study (2012) using Action Stat software version 3.1 for Windows 3.5 (Estatcamp, 2005). Considering a difference to be detected of 1.72, standard deviation of 0.44 and significance level of 0.05, the power of our sample was 1. Statistical and normality tests (Shapiro-Wilk test) were performed to anthropometric and baropodometric data using the statistical software Sigma Stat version 3.5 for Windows 3.5 (SPSSInc.2007). Data were expressed as mean ± standard deviation, minimum and maximum values. To find the difference between two groups, stabilometric data (open eyes group and closed eyes group)and gait parameters (Left and right foot), the Student t test for normally distributed data and non-parametric tests (Mann-Whitney or Wilcoxon test) for distribution with non-normal data, was used. To correlate stabilometric parameters and gait symmetry, Pearson's correlation coefficient was calculated for data with a normal distribution, and the Spearman correlation coefficient was used for non-parametric data. The r Spearman was qualitatively assessed as follows: r=1 (perfect correlation), $0.7<r<0.9$ (strong correlation), $0.4<r<0.7$ (moderate correlation), $0.2<r<0.4$ (low correlation), and r=0 (zero correlation). Pearson r correlations 0.10–0.29 were considered weak, values 0.30–0.49 were considered moderate, and values 0.50–1 were considered strong. For all analyses, the level of significance was set up at $p<0.05$.

## Results

### *Baropodometric data*

The stabilometric parameters showed no significant difference between eyes open test and eyes closed tests in preschool children (Table 2).

The baropodometric parameters did not differ between the feet, as shown in Table 3.

Table 2
*Stabilometric parameters in preschool children.*

| Parameters | Open eyes | | Closed eyes | | |
|---|---|---|---|---|---|
| | **Mean ± SD** | **Minimum–maximum value** | **Mean ± SD** | **Minimum–maximum value** | **P value** |
| Eliptic surface (mm$^2$) | 243.22±248.51 | 14.46-1094.85 | 306.54±703.96 | 9.20-4819.96 | p = 0.28 |
| Excentricity index (%) | 33.60±16.15 | 4.90-71.30 | 38.29±22.15 | 3.20-94.60 | p = 0.23 |
| Oscillation length (mm) | 496.60±291.95 | 168.90-1374.30 | 441.48±251.28 | 66.40-1370.90 | p = 0.40 |
| Axial inclination ($^o$) | 0.16±48.93 | -62.70-69.50 | -1.96±45.67 | -70.00-64.70 | p =0.70 |
| Average speed (mm/s) | 15.98±9.24 | 5.62-45.67 | 14.57±8.21 | 5,36-45,56 | p =0.44 |
| Average speed A-P (mm/s) | 8.77±5.69 | 2.51-24.79 | 8.13±4.76 | 2.23-26.10 | p =0.83 |
| Average speed L-L (cm/s) | 11.64±6.67 | 3.39-36.37 | 10.46±6.14 | 3.58-31.94 | p =0.32 |

Data expressed as mean ± standard deviation. SD, standard deviation; A-P, antero-posterior; L-L, side-to-side.

Table 3
*Gait parameters in preschool children.*

| Parameters | Left foot | Right foot | P value | Symmetry angle |
|---|---|---|---|---|
| Surface (cm$^2$) | 44.12±16.44 | 43.18±17.39 | 0.78 | -0.88±12.34 |
| Load (kg) | 50.65±10.83 | 49.34±10.83 | 0.55 | -0.69±13.12 |
| Maximum pressure (g/cm$^2$) | 568.91±202.84 | 605.67±289.62 | 0.70 | 0.67 ± 13.63 |
| Averagepressure (g/cm$^2$) | 449.29±188.79 | 480.88±254.88 | 0.78 | 0.88±12.34 |
| Time (s) | 0.59±0.25 | 0.56±0.17 | 0.78 | -1.72±8.27 |
| Speed (cm/s) | 70.15±23.75 | 71.31±39.08 | 0.65 | -0.40±7.56 |
| Step (cm) | 34.45±9.10 | 33.37±7.44 | 0.54 | -0.61±8.85 |
| Cadence (steps/min) | 61.92±17.64 | 63.50±17.83 | 0.55 | 0.48±2.58 |

Data expressed as mean ± standard deviation.

## Correlation of stabilometric parameters and gait symmetry

### *Elliptical surface*

We did not find a relationship between elliptical surface and symmetries of the following parameters: surface (R=0.02;*p*=0.89), load (R=−0.02;*p*=0.87), maximum pressure (R=−0.09;*p*=0.52), average pressure (R=−0.02;*p*=0.88), time (R=0.03;*p*=0.81), speed (R=0.05;*p*=0.72), step (R=0.15;*p*=0.31) and cadence(R=−0.02;*p*=0.88).

### *Eccentricity index*

We did not find a relationship between eccentricity index and symmetries of the following parameters: surface (R=−0.16;*p*=0.24), load (R=−0.15;*p*=0.28), maximum pressure (R=0.18;*p*=0.20), average pressure (R=0.16;*p*=0.24), time (R=−0.06;*p*=0.67), speed (R=0.04;*p*=0.79), step (R=0.03;*p*=0.82) and cadence (R=−0.14;*p*=0.36).

### *Oscillation length*

We did not find a relationship between length of oscillation and symmetry surface (R=−0.09; *p*=0.52), symmetry load (R=−0.13; *p*=0.35), symmetry maximum pressure (R=0.03; *p*=0.78), symmetry average pressure (R=0.09; *p*=0.53), symmetry time (R=−0.09; *p*=0.52), symmetry speed (R=0.07; *p*=0.63), symmetry step (R=0.003; *p*=0.98), symmetry of cadence (R=−0.20; *p*=0.20).

### *Axis inclination*

We found a moderate relationship between axis inclination and cadence symmetry (R=0.40; *p*=0.007), but we did not find a relationship between axis inclination and symmetries of the following parameters: surface (R=−0.07; *p*=0.62), load (R=−0.10; *p*=0.47), maximum pressure (R=0.05; *p*=0.71),average pressure (R=0.07; *p*=0.62), speed (R=0.001; *p*=0.99), time (R=−0.08; *p*=0.53) and step (R=−0.09; *p*=0.56).

### *Average speed oscillation*

We did not find a relationship between average speed and symmetries of the following parameters: surface (R=−0.13;*p*=0.33), load (R=−0.17;*p*=0.22), maximum pressure (R=0.08;*p*=0.56), average pressure (R=0.13;*p*=0.34), speed (R=0.08;*p*=0.60), time (R=−0.11;*p*=0.42), step (R=−0.03;*p*=0.83) and cadence (R=−0.19;*p*=0.22).

### *AP average speed*

We did not a relationship between AP average speed and symmetries of the following parameters: surface (R=−0.08;

$p$=0.53), load (R=−0.12; $p$=0.39), maximum pressure (R=0.03; $p$=0.81),average pressure (R=0.08; $p$=0.54), speed (R=0.07; $p$=0.65), time (R=−0.13; $p$=0.35), step (R=−0.01; $p$=0.90) and cadence (R=−0.14; $p$=0.36).

### *LL average speed*

We did not a relationship between the LL average speed and symmetries of the following parameters: surface (R=−0.15; $p$=0.29), load (R=−0.19; $p$=0.18), maximum pressure (R=0.10;$p$=0.49), average pressure (R=0.15; $p$=0.29), speed (R=0.07; $p$=0.62), time (R=−0.11; $p$=0.43), step (R=−0.03; $p$=0.81) and cadence (R=−0.17; $p$=0.26).

## Discussion

The objective of this study was to correlate the postural sway parameters and symmetry of gait parameters in preschool children.

The sensory systems that are related to the balance include vision, proprioception, and the vestibular system[15]. Therefore, we were hoped that, without the aid of vision, all the parameters related to the static balance with eyes closed were statistically different from those with eyes open. However, the data in this study do not confirm this hypothesis. Some authors state that at about seven years of age visual information does not significantly appear to improve the maintenance of static balance, suggesting that at this age posture control does not depend primarily on sight, but on other stimuli such as the proprioceptive ones[16].

In all analyzed gait parameters, a moderate correlation between the cadence symmetry of gait and the axial inclination of the ellipse stabilometric was found.The cadence symmetry, i.e., the symmetry of the number of steps to the left and right foot per minute during walking, is related to the direction of the CoPdisplacement, which depends on the body support base during static posture. Grasso, Zag, and Lacquaniti[7], when studying the interaction of stooped posture with gait pattern, suggest that there is anintegrated control of gait and posture and that these two motor functions share some common principles of spatial organization.

In a study with chronic hemiparetic patients, the authors associate the speed of the gait to postural sway, revealing that increased lateral sway over the position at rest was indicative of restricted speed performance while walking. Patients with greater asymmetry in the balance reached maximum speed performance at lower speed levels[9].

Although plenty of information is already available on gait in developing children, we are not yet able to fully understand the relationship between the static balanceand the gait when the central nervous system ismaturing. Studies in this area should be intensified.Despite the limitations of the subject variability of baropodometric and stabilo metric parameters found in this age group, the use of indices such as gait symmetry can facilitate the analysis of these results, as the non-dimensional normalization of gait parameters using either length of the lower limbs or height is indicated in the literature, although the process cannot remove the inter-subject variability[17].

Another limitation of this study was a convenience sample that interferes with the representation of the population. However, given the time, financial, material and human resources constraints necessary to carry out this research, this research becomes relevant because of theshortage of data and reference values for posture and gait analysis in preschool children, i.e., those in neuro psychomotor development. Despite the variability of parameters in child development, references in this age are important for health professionals to identify early changes in postural control and gait of young children.

## Conclusion

This study concluded that there is a relationship betweenpostural sway parameters and gait symmetry in preschool children, but specifically in the symmetry of the cadence of the feet while walking to the direction of pressure center displacement during bipedal posture.

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