



Faculty Of physical Therapy,
Cairo University



Correlation between Foot Pronation and Body Mass Index in Spastic Diplegic Children

Shorouk A. W. El-Shennawy*, Mona H. G. ElLaithy** and Olfat I. Ali***

*Department of Physical Therapy for Pediatrics, Cairo University, Egypt.

**Department of Physical Therapy for Musculoskeletal Disorders and its Surgery, -Cairo University, Egypt.

***Department of Basic Sciences, Cairo University, Egypt.

ABSTRACT

Background: Spastic diplegia is a form of cerebral palsy (CP) primarily affecting the legs. It is characterized by spasticity, shortened tendoachilis and may be associated with pronated foot; if the peroneal muscles are shortened. Excessive foot pronation is the most common complaint related to foot deformity in children with spastic CP.

Objective: To investigate if there is a correlation between the child's weight (as quantified by BMI) and the degree of foot pronation. **Methods:** Twenty child with spastic diplegia participated in this study. All children presented with excessive foot pronation. The degree of foot pronation was evaluated by Computerized photogrammetry using CorelDraw Graphics software. Percentile body mass index (PBMI) was calculated for each child by two methods. **Results:** No statistically significant correlations were found between PBMI and the degree of foot pronation in both sides. The correlation (r) value of Rt and left side correlation was - 0.140 and - 0.430; and the P-values were 0.555 and 0.058; respectively. **Conclusion:** The results of current study shows that there is no correlation between PBMI and the degree of foot pronation in children with spastic diplegia.

INTRODUCTION

Cerebral palsy (CP) is a heterogeneous group of permanent, non-progressive motor disorders of movement and posture. It is primarily caused by chronic brain injuries that may originate within the prenatal, perinatal, or postnatal periods¹⁵.

CP is the leading cause of childhood disability²⁵. The reported incidence of CP varies among literature, and it ranges between

two and two and half times per 1000 live births. The number of children that CP affects has remained essentially unchanged or perhaps has risen slightly during the past 30 years¹⁵.

Diplegia is a form of CP primarily affecting the legs. It is a lifelong neurological disorder that is usually present at birth. Most children with CP will also have some arms dysfunctions, yet upper limbs involvement is less severe than that of the lower limbs.. Most children with diplegia have spasticity, and have difficulty with balance and coordination. The severity of spastic diplegic CP can vary from one patient to another. Furthermore, delayed muscle growth and spasticity cause leg muscles to be short, and consequently the range of joint motion may decrease as a child grows and the joints become stiffer. The feet and ankles present more problems than the knees due to a short tight Achilles tendon, which can lead to toe walking²⁰.

The most common spastic deformity in CP is equinus. It may be combined with an equinovalgus deformity of the foot when it is associated with pronation due to spastic peroneal muscles. Also, It may be associated with equinovarus deformity when with the tibialis posterior muscle is over-activity or spasmed¹².

Although children with CP are often viewed as undernourished and growth impaired^{7,26}, several mechanisms may increase their risk to increased weight gaining. First, children with CP are often born either small for gestational age or premature, which has been shown to be independent risk factors to obesity^{6,9}. Second, children with spastic CP

have been found to have decreased body cell mass and expanded extracellular compartment³. Moreover, the rate of accretion of fat-free mass is lower in children with spastic CP²⁴. Third, children with spastic CP who are of adequate weight for height, energy expenditure has been shown to be lower compared to that of healthy children with matched weight or age¹⁴. Fourth, individuals with CP encounter a unique set of medical and social issues specific to their disability that often restricts their participation in physical activities².

Excessive foot pronation is characterized by a flattening of the medial arch and a hypermobile midfoot. This may also place greater demands on the neuromuscular system to stabilize the foot and maintain upright stance¹⁹.

A primary cause of overpronation is subtalar eversion. When the calcaneus is everted, weight is forced onto the medial edge of the foot²⁷. Heavier body weight results in higher plantar pressures, with the largest effect imposed under the longitudinal arch and metatarsal heads¹¹.

Flat foot was found to be significantly associated with increased BMI in adults and children²³. As loading on the medial edge of the foot is an important component in the formation and development of this deformity, the degree of foot pronation may be associated with the child's weight^{17,18}.

Percentiles are the most commonly used indicator to assess the size and growth patterns of children. Percentiles are used for children and teens because the amount of body fat differs with gender and age. Percentile measures indicate the relative position of the child's BMI number among children of the same sex and age²⁸.

The purpose of this study was to investigate the association between BMI and excessive foot pronation in diplegic CP children.

SUBJECTS AND METHODS

Before initial assessment, caregivers were asked to sign an informed consent if they accepted to let their children participate in this study. This consent has been approved by the

Ethics Committee of the Faculty of Physical Therapy, Cairo University, Egypt, where the study took place.

Subjects

Twenty children with spastic diplegic CP from both sexes participated in this study. Participants were selected from the outpatient clinic of Faculty of Physical Therapy, Cairo University. Children were included if they met the following criteria: (1) Age ranged from 4-6 years, (2) Had mild degree of spasticity that ranged from 1 to 1+ grade according to modified Ashworth scale, (3) they were level II or III on the Gross Motor Function Classification System, and (4) they were able to follow orders and instructions given by the researchers. Children were excluded from the study if they had: (1) lower limb surgery, (2) received any anti spastic drugs, or (3) fixed foot deformity which could not be corrected passively.

Materials

CorelDraw software program

Computerized photogrammetry is the combination of digital photography and software such as CorelDraw²¹ that allows the measurement of horizontal and vertical distances and angles for various ends. CorelDraw Graphics Suite (X5) is non-specified postural software that was used to replace the sophisticated methods of postural assessment. This software was used to measure pronation angles. 2-D camera was used for capturing the child during standing measuring the angle between the tibia and the calcaneus. Then, photos were loaded into the program. Once the landmarks have been localized, the angle was calculated easily and fast.

Disposable Adhesive Dots

The rounded disposable adhesive dots were used to mark the bony surface landmarks of the tibial shaft and the calcaneus axis.

Procedures

Measurements of foot angulations

CorelDraw software was used for measuring pronation angle during standing from frontal view through capturing the position of the subtalar joint and measuring the

pronation angle through markers placed on the shaft of tibia and on calcaneus posterior aspect. In order to measure foot pronation, the eversion angle of the calcaneum was used to designate pronation of the subtalar joint using CorelDraw software. Four markers were placed on the posterior aspect of the leg and foot. The pronation angle was measured between the shank and the calcaneus. The shank was represented by a line connecting the knee and ankle joint centers, in relation to the line formed by two markers applied to the calcaneal bisection. The two lower markers, representing the rear foot segment, were placed below the axis of subtalar movement, the lowest being on the calcaneal tubercle and the other below the axis of subtalar movement. The upper two markers, representing the leg segment, were placed proximal to the axis of subtalar movement, in the midline of tendoachillis.

The angle was measured by drawing two lines, the first one was drawn to connect the landmarks of tibia, whereas the second line connected the markers indicating the axis of the calcaneus. Then, the intersection angle between the two lines was measured.

Calculating percentile body mass index (PBMI)

For each child PBMI was calculated with 2 different methods; an online and a manual calculations to ensure accuracy of the obtained data.

Online Calculation

In the current study, an online child and teen BMI calculator (Medscape online BMI percentile calculator) was used to get the exact percentile for the BMI of each boy or girl. The height and weight of the child was measured using the calibrated scale. The age (in years), height (in centimeters) and weight (in kilograms) of each child were fed to the corresponding web page (<http://reference.medscape.com/calculator/body-mass-index-percentile-girls>) for girls, and (<http://reference.medscape.com/calculator/body-mass-index-percentile-boys>) for boys.

Manual Calculation

BMI was calculated by dividing the weight (in kilograms) by the squared height (in meters) ($BMI = \frac{Weight (Kg)}{Height^2 (m^2)}$) [7]. BMI percentile was then calculated by plotting the BMI number on an appropriate weight-for-age growth charts (for girls and boys) to determine weight status category of the child (underweight, normal, overweight or obese).

Statistical analysis

Pearson's correlation coefficient was used to compare the association between PBMI and the degree of Rt and Lt foot pronation in diplegic CP. All analyses were done using the SPSS software version 20.0. The significance level was set at $P < 0.05$. All data are expressed as mean \pm SD.

RESULTS

Table (1): Demographic Data.

Variables	Mean \pm SD
Age (Yrs.)	5.75 \pm 2
Height (Cm)	102.4 \pm 10.1
Sex (G/B)	(No.) 11/9 (%) (55%/45%)

SD: Standard deviation, G: girl, B: Boy

As shown in Table 1, the mean age was 5.75 \pm 2 years (4-6), mean height was 102.4 \pm 10.1 cm. The percent of girls and boys within the study sample was 55% and 45%, respectively.

Table (2): Distribution of weight status category of diplegic children.

Variable	Weight status category	Number	Percentage
Weight	Underweight (<5%)	3	15%
	Normal (5 to <85%)	15	75%
	Overweight (85 to <95%)	1	5%
	Obese (>95%)	1	5%

The mean weight was 16.55 \pm 3.3 Kg. The distribution of weight status category of diplegic children was as follow; three children (15%) were underweight, 75% were normal in weight, one child (5%) was overweight, and another child (5%) was obese as shown in Table 2.

Table (3): Mean values of BMI and foot pronation.

Variables	Mean ±SD
PBMI	50.1±31.1
Rt foot pronation	17.13°±4.8
Lt foot pronation	16.9°±4.9

SD: Standard deviation, PBMI: Percentile body mass index

The mean body mass was 50.1±31.1 kg/m². Regarding foot pronation; Rt pronation mean was 17.13°±4.8, whereas that of the Lt foot was 16.9°±4.9 as shown in Table 3.

Table (4): Correlation between PBMI and Rt& Lt foot pronation.

Variable	Right foot pronation		Left foot pronation	
	R	P value	R	P value
PBMI	-0.140	0.55	-0.430	0.06

P: probability r: correlation coefficient

For the Rtside, the correlation (r) between BMI and foot pronation (Figure 1) was -0.140, with P value 0.55. Whereas the correlation between BMI and Lt foot pronation (Figure 2) was r= -0.430, with p value 0.06 as shown in Table 3. This declared no statistical association between BMI and foot pronation on both sides.

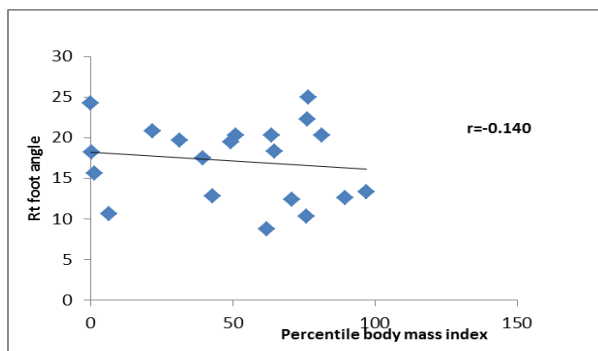


Fig. (1): Association between PBMI & Rt foot pronation.

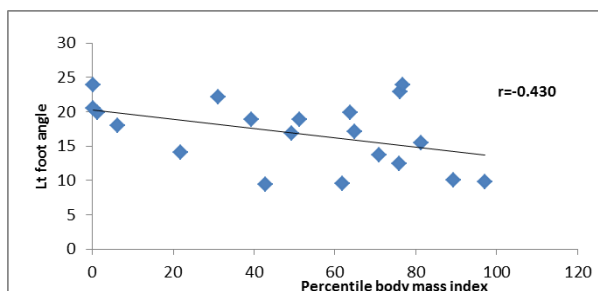


Fig. (2): Association between PBMI & Lt foot pronation.

The results of the current study showed that there was no correlation between BMI percentile and the degree of foot pronation in children with spastic diplegia. Excessive foot pronation is the most common complain related to foot deformity in children with CP⁸.

Eversion component of the excessive pronation causes more weight to be placed on the medial side of the foot²⁷. Increasing the weight of the child is expected to increase the load imposed on the medial structures.

Weight may have larger impact on the degree of foot pronation in higher weight zones. Obese individuals have an altered gait with more extensive rearfoot eversion¹⁶. Heavier body weight results in higher plantar pressures, with the largest effect under the longitudinal arch and metatarsal heads².

No significant correlation reported when comparing foot pronation and BMI. It should be noted that 2 outlier data points were found in our sample; one represented an overweight and the other an obese child (Table 2). Larger sample is recommended to overcome such sampling error.

The possible cause of the current results may be explained by BMI percentile of most of our sample (75%) being within the normal weight zone, while 15% were underweight and only 10% were overweight and obese.

BMI percentile was used in this study to express body weight of the children. Percentiles are the most commonly used indicator to assess the size and growth patterns of individual children in the United States. Percentiles are used for children and teens because the amount of body fat differs between boys and girls and body fat also changes with age. The percentile indicates the relative position of the child's BMI number among children of the same sex and age²⁸. The growth charts show the weight status categories used with children and teens: underweight, normal weight, overweight, and obese.

Foot pronation may be attributed to first, mild degree of spasticity that ranged from 1 to 1+ grade, as spasticity is one of the leading causes to foot deformity. Second, Over pronation may occur for anatomical reasons, such as a tibia vara of 10 degrees or more,

DISCUSSION

forefoot varus, leg length discrepancy, and ligamentous laxity¹. As the height of the medial longitudinal arch is lost, a cascade of biomechanical problems related to the causes of hyperpronation may follow²⁷. Third, a tight Achilles tendon places the calcaneus not only in plantar flexion, but also eversion²⁷. Both of these actions translate force medially on the talus and downwards and medially on the navicular, causing subsequent loss of height of the medial longitudinal arch^{12,22}. Fourth, weakness and fatigue of foot plantar flexors muscles may result in an increased foot pronation and collapse of the medial longitudinal arch as quantified by navicular drop¹⁰. Finally, with ambulation, dynamic support from the posterior tibial tendon (PTT) is needed to maintain the superior position of the navicular bone. A weak PTT is unable to support the position of the navicular bone, and, once again, a loss of the medial longitudinal arch may occur. Collapse of the medial longitudinal arch everts the calcaneus in relation to the talus; that is, the foot pronates^{4,5}.

Conclusion

Based on our results, no correlation exists between percentile BMI and the degree of foot pronation. It is suggested that future research consider recruiting a larger sample size with foot pronation greater than 17°.

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المخلص العربي

الارتباط بين كعب القدم و مؤشر كتلة الجسم في الأطفال المصابين بالشلل الدماغي التصلبي

مقدمة: يعتبر الشلل النصفي المتصلب من أنواع الشلل الدماغي التي تصيب الأرجل بشكل أساسي ويتميز بالتصلب، قصر وتر أكيليس، وقد يصاحبه كعب القدم إذا أصيبت عضلات الكأبة بالقصر . ويعد كعب القدم المفرط أكثر الشكاوى المتعلقة بتشوّهات القدم في الأطفال المصابين بالشلل الدماغي . **أهداف البحث :** استقصاء هل يوجد علاقة بين وزن الطفل (ممثلًا بمؤشر كتلة الجسم المئوي) ودرجة كعب القدم . **وسائل البحث :** شارك في البحث 20 طفل وطفلة مصابين بالشلل الجانبي المتصلب. يعانون جميعاً من كعب القدم المفرط. قيمت درجة كعب القدم بالتخطيط الفوتوغرافي بالحاسوب باستخدام تطبيق كوريل درو للرسوم . أما مؤشر كتلة الجسم المئوي فتم حسابه لكل طفل بطريقتين مختلفتين . **النتائج :** أسفرت النتائج عن عدم وجود ارتباط ذو دلالة إحصائية بين مؤشر كتلة الجسم ودرجة كعب القدم اليمنى ولا درجة كعب القدم اليسرى حيث كان معامل الارتباط (-0.140 و -0.430 بالترتيب) وقيمة الخطأ (0.555 و 0.058 بالترتيب) . **الخلاصة :** أظهرت نتائج الدراسة الحالية عدم وجود ارتباط بين مؤشر كتلة الجسم المئوي ودرجة كعب القدم في الأطفال المصابين بالشلل الجانبي المتصلب.