

## INFLUENCE OF BODY MASS INDEX ON DISTANCE AND TEMPORAL CHARACTERISTICS OF GAIT IN CHILDREN WITH SPASTIC DIPLEGIA HAVING JUMP GAIT

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### ABSTRACT

#### BACKGROUND

One of the leading causes of motor disability in children is cerebral palsy.<sup>1</sup> Various abnormal patterns of gait are described in this population of children. Jump gait is one of the common gait patterns in children with spastic diplegia. Various factors affect the gait characteristics of children with spasticity e.g. severity of spasticity, poor voluntary control, poor endurance of muscles, age, weight and Body Mass Index (BMI), balance etc. 3 D gait analysis helps us to understand these gait patterns better. This study aims to describe the variation in distance and temporal characteristics of jump gait in children with spastic cerebral palsy having different BMI.

#### MATERIALS AND METHODS

Clinical evaluation, measurement of Body Mass Index (BMI) and 3 D gait analysis data of 14 children with spastic diplegia walking with jump gait were compiled after informed consent. Spatial parameters studied were stride length, step length and step width. Temporal parameters studied were cadence, mean velocity, and stride time. Children were grouped into heavy and not heavy cohorts according to BMI measurement. The spatiotemporal characteristics were studied using appropriate statistical analysis like independent t test.

#### RESULTS

The mean age of the study group was 8.4 years and the mean weight was 27.1 kg. The mean height was 117.8 cms. The mean BMI of the group was 18.7± 5.6 Kg/meter sq. 6 children belonged to the GMFCS I, and 8 belonged to GMFCS II. According to age matched BMI calculations 2 children were underweight, 6 were normal, one obese and 5 pre-obese. The stride time and cadence of the group of children who were heavier was lesser than those who were not heavy as measured with BMI. The mean velocity was less when compared to those children who were not heavy. Heavier children had a slightly wider step width (p value- not significant).

#### CONCLUSION

In this cohort of children from India, heavy children with spastic diplegia walking with jump gait were slower in walking than not heavy children. Heavy children with jump gait had a slightly wider base of support. (p value was not significant).

#### KEYWORDS

Cerebral Palsy, Spastic Diplegia, Jump Gait, Spatiotemporal Characteristics, 3 D Gait Analysis, Obesity, BMI, Body Mass Index.

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#### BACKGROUND

Cerebral palsy is the leading cause of locomotor disability in children around the world.<sup>2</sup> Four pathological gait patterns described in spastic cerebral palsy are equinus gait, crouch gait, jump gait, stiff knee gait.<sup>3</sup> These gait abnormalities vary from a mild toe walking to severe scissoring with crouch gait needing assistance.

Various factors affect the gait characteristics of children with spasticity like severity of spasticity, poor voluntary control, age, poor endurance of muscles, balance, weight of the child etc.

Traditional thought is that obesity apparently makes the gait slower even in normal children. Body mass index is a good indicator of obesity in children, hence this study aims to study the influence of variation in Body Mass Index (BMI) on the spatiotemporal characteristics of gait in spastic children with jump gait. Chronic disease risk such as obesity is also higher among adults with cerebral palsy than the general population. Common problems include increased pain, reduced flexibility, increased spasms and contractures according to Peterson.<sup>4</sup> Children with cerebral palsy (CP) have reduced levels of physical activity compared with children without physical disability and experience risk factors for becoming overweight or obese according to Pascoe.<sup>5</sup>

The Body Mass Index (BMI) ( $\text{weight (kg)} / (\text{height (m)}^2)$ ) is widely accepted as providing a convenient measure of a person's fatness.<sup>6</sup> Kids who measure at the 85th to 94th percentiles are considered overweight, because of excess body fat or high lean body mass. A child whose BMI is between the 5<sup>th</sup> percentile to 85th percentile is in the healthy weight range. A child with a BMI below the 5<sup>th</sup> percentile is considered underweight.<sup>7</sup>

Palisano et al described a simple classification to measure gross motor function, the Gross Motor Functional Classification System (GMFCS). This was stratified into five levels.

Gait analysis is defined as the systematic study of animal locomotion, more specifically the study of human motion, using the eye and the brain of observers, augmented by instrumentation for measuring body movements, body mechanics, and the activity of the muscles.<sup>8</sup>

### Objective of The Study

To study the influence of variation of Body Mass Index (BMI) on the distance and temporal characteristics of gait in children with spastic diplegic walking with jump gait.

### MATERIALS AND METHODS

Initially details of spastic children with jump gait who underwent routine 3 D gait analysis was compiled and analysed after informed consent.

Clinical and physical evaluation and 3 D gait analysis data of children with spastic diplegia walking with jump gait was entered into a performa after informed consent. Calculation of body mass index was also performed. All these children continued their standard treatment including anti spastic drugs, orthosis, physiotherapy, occupational therapy, serial casting and other supportive treatment as needed. They also continued their schooling and routine activities.

Clinical evaluation included screening of the systems with special emphasis to muscle power, tone, range of motion of the joints of the lower extremity. Goniometer was used to measure the joint angles. Deformities of the hip, knee and ankle was noted. More than 10 degree of flexion contracture at the hip was considered as having hip flexion deformity, more than 25 degree of flexion contracture at the knee was classified as having knee contracture. Children

having less than 80 degree of total adductor angle was considered as having adduction contracture of the hip. Further anthropometric data measured included weight, height, ASIS width, pelvic depth, knee diameter, ankle diameter, leg length, thigh and calf circumference, as per the Simple Helen Hayes protocol using standard weighing machine (bathroom scale), measuring tape and beam calipers.

3 D gait analysis acquisition was done at the Gait analysis lab at the Department of Physical Medicine and Rehabilitation, Government Medical College, Thiruvananthapuram. After anthropometric measurements optometric markers (reflective) were placed on 15 sites of the lower limbs namely sacrum both anterior superior iliac spine, mid-thigh, femoral condyles, mid-calf, lateral malleolus, heel and second metatarsal head. Objective gait acquisition was done using BTS Smart DX 600 motion analysis system after calibration. The equipment included 4 infrared cameras, two video cameras, two force plates on a 5 meter walk way. The child was made to walk on the walk way while the gait was acquired using the above system, one standing session and few walking sessions are taken and the best selected for processing using Simple Helen Hayes protocol.

Body Mass Index is a simple calculation using a person's height and weight. The formula is  $\text{BMI} = \text{kg}/\text{m}^2$  where kg is a person's weight in kilograms and  $\text{m}^2$  is their height in meters squared.

In adults a BMI of 25.0 or more is overweight, while the healthy range is 18.5 to 24.9. However, in children, they may be categorized based on their BMI for age percentiles. Kids who measure over the 85<sup>th</sup> percentile as pre-obese and those above 95 percentile are considered obese or overweight, because of excess body fat or high lean body mass. A child whose BMI is between the 5<sup>th</sup> percentile to 85<sup>th</sup> percentile is in the healthy weight range. A child with a BMI below the 5<sup>th</sup> percentile is considered underweight.

### Study Design

Retrospective Descriptive Study

### Study Setting

Department of Physical Medicine and Rehabilitation, Government Medical College, Thiruvananthapuram.

### Duration

January 2013 to June 2016

### Study Population

Clinically diagnosed children with spastic diplegia walking with jump gait pattern who attended the cerebral palsy clinic of the Institute and who have undergone 3 D gait analysis during the above period.

### Inclusion Criteria

- Spastic diplegic children with jump gait pattern as diagnosed clinically.
- Children classified as GMFCS level I and II clinically.

- Children who can walk more than five meters independently.

**Exclusion Criteria**

- Spastic diplegic children with ongoing seizures.
- Spastic diplegic children with other patterns of gait like crouch, hemiplegic, equinus and ataxic gait patterns.

**Ethical Issues**

The study was started after institutional ethical committee clearance.

Data was collected and processed after informed consent.

**Sample Size**

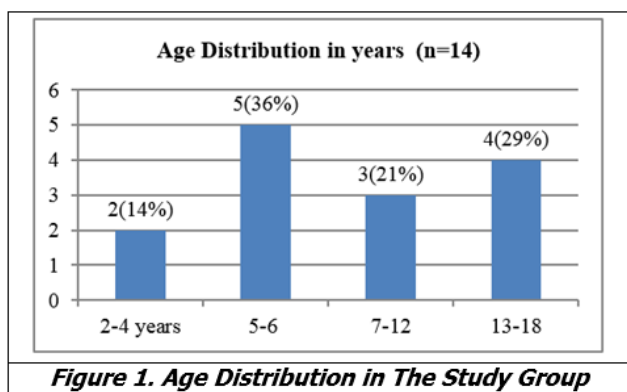
Though approximately 100 children with cerebral palsy attended the CP clinic, the number of children with spastic diplegia having jump gait pattern who underwent 3 D gait analysis was 14 during the above period. Consecutive convenient sampling was used.

**Statistical Tests Used**

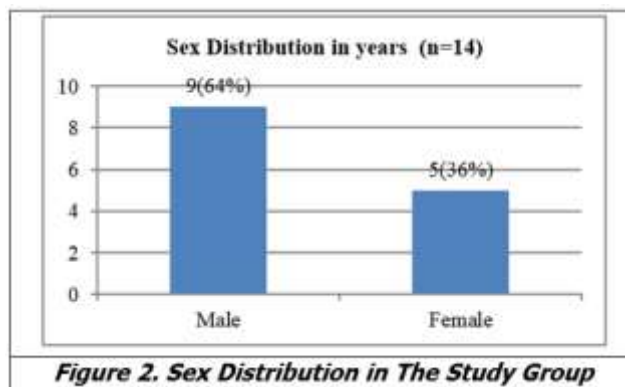
Categorical and quantitative variables were expressed as frequency (percentage) and mean ± SD respectively. Independent t test was used for comparison of means of selected parameters based on BMI. p value <0.1 was considered the threshold for statistical significance. Statistical analyses were performed by using statistical software package SPSS. The children were classified according to their age, sex, GMFCS and BMI. And the spatiotemporal (distance and temporal) characteristics plotted and analysed against BMI. The children classified according to age matched BMI chart was further grouped into heavy children (obese and pre-obese) and not heavy children (normal BMI and underweight) for ease of comparison.

**RESULTS**

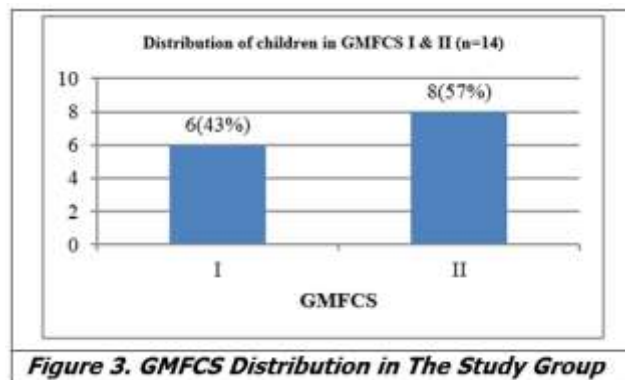
14 children with spastic cerebral palsy having diplegia and walking with jump gait were included. The 3D gait analysis report and clinical evaluation revealed the following:



**Figure 1. Age Distribution in The Study Group**



**Figure 2. Sex Distribution in The Study Group**



**Figure 3. GMFCS Distribution in The Study Group**

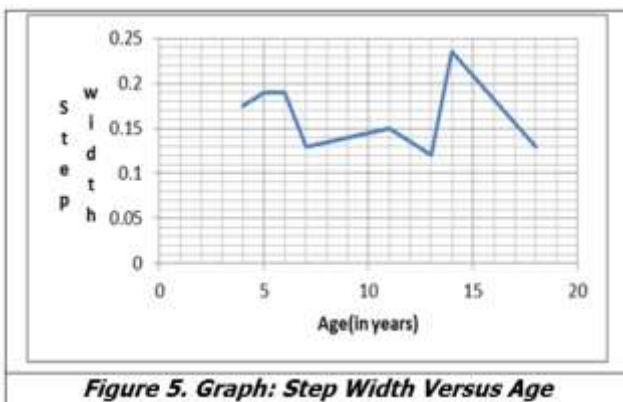
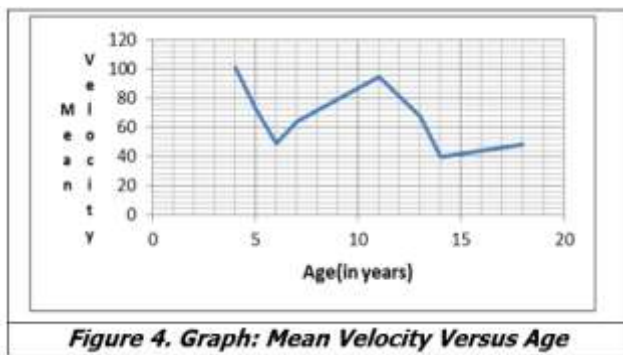
The mean age of the study population was 8.4± 4.6 years, the mean weight was 27.1 ± 12.5 kg. The mean height was 117.8± 13.7 cm. The group consisted of 9 boys and 5 girls (Figure 2). 6 children belonged to the GMFCS I and 8 belonged to GMFCS II (Figure 3).

The mean BMI of the group was 18.7± 5.6 Kg/meter sq. BMI measurements of the children showed that 2 children were under weight, 6 were normal and 5 pre-obese and one obese (above 95<sup>th</sup> percentile) when classified according to age matched BMI chart.

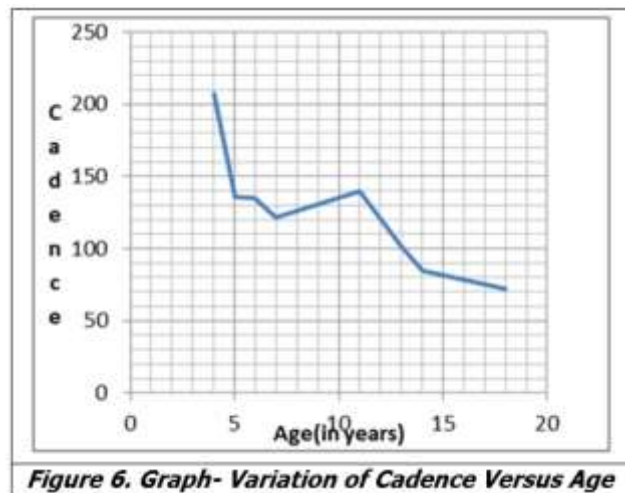
BMI	Count	Percent
Under Weight	2	14.3%
Normal	6	42.9%
Pre-Obese	5	35.7%
Obese	1	7.1%

**Table 1. Percentage Distribution of the Study Sample According to BMI**

The mean cadence of the group was 129.7 steps per minute. Cadence was found to decrease with age. The mean velocity was 66.9 cm/s and was found to be decreasing as age increased (Figure 4). Stance and swing time also increased with age.



The mean stride length was 79.6 ± 14 cms on the right and 79.9 ± 14 cm on the left. The mean step width was 17.3 ± 4 cm (0.173 M) and the mean step length on the right was 36.5 ± 8 cms and 35.2 ± 8 cms on the left. The distance parameters increased up to 12 years of age and then decreased, probably indicating a disturbance at the growth spurt during adolescence.

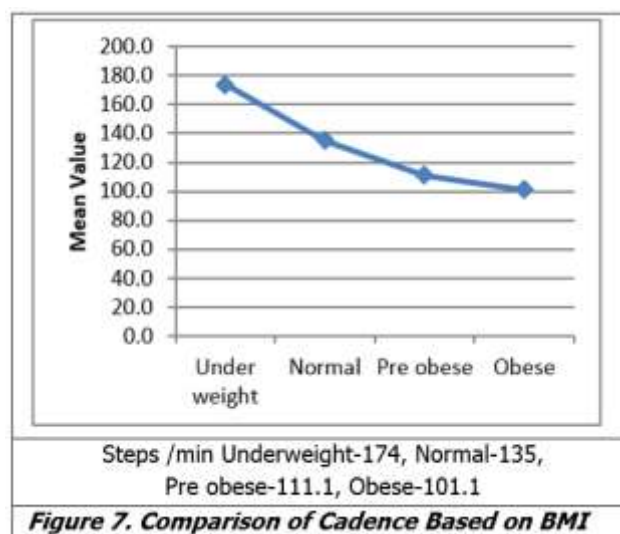


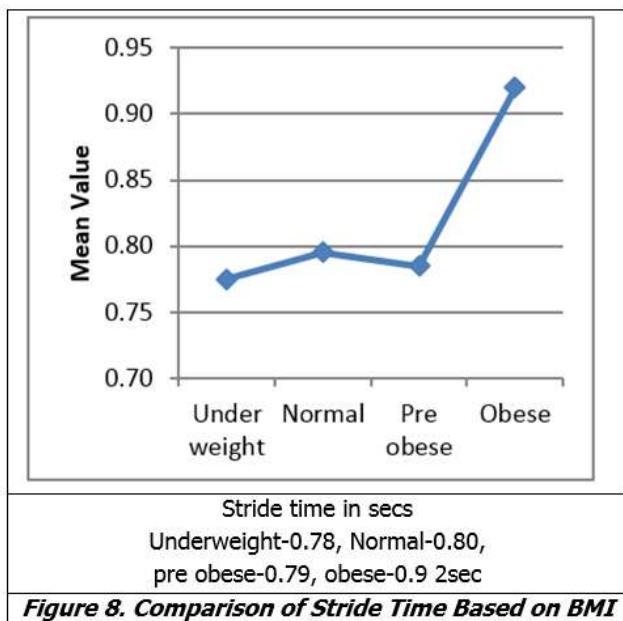
**Body Mass Index (BMI)**

	Not Heavy			Heavy			T	p Value
	Mean	SD	N	Mean	SD	N		
Stride Length (m)	0.79	0.09	8	0.81	0.20	6	0.22	0.832
Cadence (Steps/min)	144.8	41.3	8	109.5	32.1	6	1.73	0.098
Step Width (m)	0.17	0.04	8	0.18	0.06	6	0.69	0.506
Step Length (m)	0.36	0.06	8	0.36	0.09	6	0.06	0.956
Mean Velocity (cm/sec)	73.3	23.3	8	58.5	23.5	6	1.17	0.266
Stride Time (sec)	0.89	0.23	8	1.19	0.37	6	1.9	0.082

**Table 2. Comparison of Selected Variables Based on BMI**

The cadence was more for the not heavy children by 24.4% (144.8 steps /minute for the not heavy group and 109.5 steps /minute for the heavy group). The mean velocity was 20.2% more for the not heavy children (73.3 cm/s for the not heavy group and 58.5 cm/s for the heavy group). Stride time was more by 25.2% in the heavier group (0.89 sec for the not heavy group and 1.19 sec for the heavy group). The step lengths were the same, and the step width was slightly more for the heavier group (0.17 m for the not heavy group and 0.18 m for the heavier group). There was no statistical significance when the threshold for statistical significance was put as (p value <0.05). However, there was statistical significance for cadence and stride time when the threshold was raised to (p value <0.1).

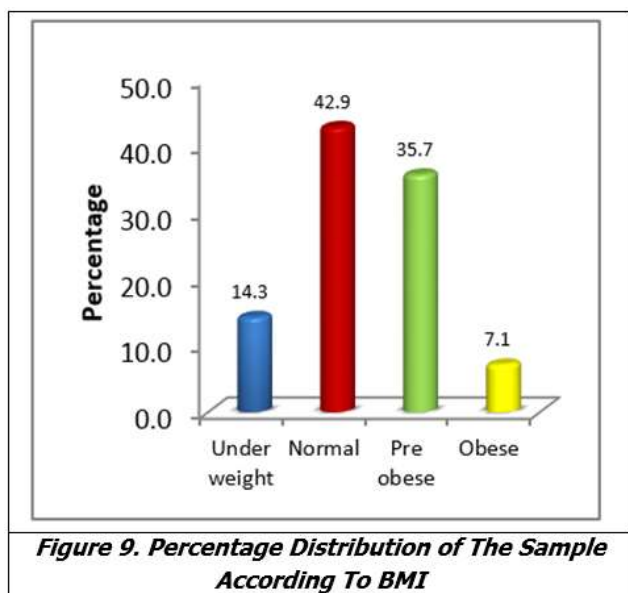




**DISCUSSION**

The aim of the study was to describe the temporal and distance characteristics of gait children with spastic diplegia walking with jump gait in relation to their body mass variation.

7.1% percentage of our cohort of ambulant Indian children with spastic diplegia walking with jump gait were obese, 35.7% were pre-obese, 42.5% were normal and 14.3% were under weight (fig no 9) as compared to the study by Pascoe J on the Australian population of children with Cerebral Palsy (CP) where 19.4% of ambulant children with CP were overweight or obese.<sup>5</sup>



The cadence and mean velocity were found to be decreased as age advanced, correspondingly the stance time & swing time also increased as the child grew older. The step length and step width decreased after age 12.

Chang, Ju Kim et al in 2015, studied the spatiotemporal gait parameters of children with spastic diplegia and

compared it with normal children (normal children n=8, spastic diplegic children n=8) and found that walking velocity, cadence, stride length and step width of children with CP were 60%, 77%, 73% and 160% respectively of the normal children. The spatiotemporal parameters of our study group when compared with that of the normal children studied by Chang Ju Kim revealed values of 62%, 108%, 69% and 234% respectively.

Parameters	Chang et al.	Present Study
Walking Velocity	60%	62%
Cadence	77%	108%
Stride Length	73%	69%
Step Width	160%	234%

**Table 3. Comparison of The Results of Present Study with That of Chang et al**

Our study showed increase in cadence & step width when compared with the study by Chang et al<sup>9</sup> when plotted against the normative data from the study by Chang. Thevenon et al described that paediatric gait pattern starts to change by about 7 years of age,<sup>10</sup> hence we grouped the children as below 7 years of age and above 7 years.

Independent t test compared the spatiotemporal characteristics of gait in children with diplegia above 7 years and those below 7 years of age and found that children below 7 years had decreased cadence, mean velocity and step width when compared to those children above 7 years of age.

However, for those above 12 years of age there was a decrease in step length and step width.

Girls had lower cadence and mean velocity than boys, but the stance time step width and step length was more for the girls. The p values were not statistically significant.

The impact of BMI on gait has been assessed by few authors comparing obese children with non-obese children. Obese children are known to have a longer cycle duration, lower cadence, longer stance duration and greater stride width.<sup>11</sup>

Pre-obese & obese according to BMI children were classified as heavy and the rest as not heavy. The group of heavy children showed decreased cadence and mean velocity. They also manifested with increased stride time and step width (however statistical significance was obtained only for cadence and stride time when the threshold for statistical significance was at p <0.1)

Thevenon et al studied the normative data of distance and temporal characteristics of gait in French children between 6 yrs and 12 years and concluded that though mean velocity and step length increased as age advanced the swing time, stance time and double support time remained static after 7 years of age.<sup>10</sup>

When compared with normal children the children with jump gait in our study had a mean velocity of 66.92 cm/sec and cadence of 129.77 steps per minute. There was also a deterioration of spatiotemporal parameters as age advanced. A study by Thevenon et al revealed significant differences in stance time and double support between



overweight and non-overweight children who were normal, whereas the differences in cadence and base support did not achieve statistical significance.<sup>10</sup>

In the present study heavy children with diplegia had significantly increased stride time than not so heavy children. Heavier children had slower gait and slightly wider base of support than not so heavy children (p values were not significant).

### CONCLUSION

Our study concluded that overweight children with spastic diplegia walking with jump gait had slower cadence and were slower in walking than non-overweight children.

Heavier children with jump gait had significantly longer stride time.

Overweight children with jump gait also had a slightly wider base of support which manifested as larger step width. (p value was not significant)

Larger studies need to be taken up in future to compare with other types of spastic gait.

### Limitation of the Study

Small sample size could be the reason for less significance when the threshold of significance was at  $p < 0.05$ . It was a retrospective study and normative data for Indian population was unavailable. The frankly obese group had only one child, hence analysis was not quite significant.

### Acknowledgment

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