ABSTRACT

Background: Efficacy of rehabilitation program for subjects with orthosis with objective measurement. The study aiming to objectively compare the PCI and walking speed of normal children with ambulatory spastic diplegic. Also we aimed to analyze whether BMI had impact on energy cost.

Method: 41 normal children and 41 community walking spastic diplegic aged between 6 to 18 yrs. were assessed to compare the PCI. Speed of walking and heart rate were checked constantly both barefoot and in shoes in normal children and with and without conventional AFO in children with spastic diplegic at their chosen velocities over four consecutive lengths of a 12.5m walkway i.e. total 50m., Pre and Post readings are taken. Heart rate is affected by speed; PCI with speed of walking and heart rate was calculated for each child.

Result: The mean PCI in shoes and barefoot was same in normal children i.e. 0.05 ±0.039 beats/meter. The PCI for children with pathological gait i.e. spastic diplegic without orthosis and with orthosis is 0.199 ±0.176 and 0.104± 0.093 beats/meter appreciably greater than that for normal children (p less than 0.05).

Conclusion: This study showed that walking with orthosis in spastic diplegic CP children showed higher costs of energy and slower walking speed compared normal children with age matched. The PCI of walking, with orthosis in children with spastic Diplegic cerebral palsy is less as compared to without orthosis i.e. gait is more energy efficient with orthosis. BMI doesn't show any correlation with PCI further study may require.

Keywords: Cerebral Palsy (CP), physiological cost index (PCI), Energy Expenditure, Gait, Ankle Foot Orthosis (AFO), Spastic Diplegic, Body Mass Index (BMI).

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INTRODUCTION
Cerebral palsy is a non-progressive motor disorder caused due to an insult to immature brain. This damage can occur either prenatal, perinatal or postnatal period of pregnancy [1,2]. CP is the one of the commonest movement disorders seen in paediatric population. Again in that Spastic diplegia is most common among all categories. Prevalence is 2.1 per 1,000 live births. Children with CP have limited functional level due to primary & secondary functional impairments like movement difficulty, problems with balance & co-ordination [3]. Physiotherapeutic interventions are designed to improve the functional level of the child. Ambulation is a one of the major concern. An intervention includes encouragement of the patient, improving strength and gait, stretching programs to limit contractures, etc. Gait effectiveness is well-defined as energy cost per distance travelled. Pathological gait is usually associated with amplified energy expenditure. This may bounds the capacity of spastic diplegic child with a motor disorder to function in the community. A universal measure of energy expenditure may be useful to compare normal gait with pathological gait[4,5], to score the severity of a motor disorder, and to provide an outcome measure to evaluate the efficacy of intervention. Energy studies may be useful in describing the natural history of motor disorders (Duffy et al. 1996), for which prescription of orthosis plays a major role. It helps to correct the alignment and reduce the extra muscle work [7]. But many a times these orthosis are used only as night splints or for ambulation outside the house and rarely for ambulation around the house.

Calculation of the energy expenditure of walking is frequently achieved to evaluate the efficiency of walking systems [7]. The standard methods for assessing energy cost is the direct measurement of oxygen consumption (VO\textsubscript{2}) but it is normally unavailable in the clinical setting and in addition, is cumbersome in its application to children, particularly those with physical handicaps. The Physiological Cost Index (PCI) first was introduced by MacGregor as method based on linear correlation between VO\textsubscript{2} and heart rate (HR) [8]. It needs simply recording of HR at rest and while walking. Measuring the PCI has been the focus of many publications for patients with different[9-16].

Efficacy of rehabilitation program for subjects with orthosis with objective measurement.

We started this study aiming to objectively compare the PCI and walking speed of normal children with ambulatory spastic diplegic. Also we aimed to analyze whether BMI had impact on energy cost.

NEED OF STUDY: There is a significant correlation of gait impairment with elevated oxygen cost. Calculation of oxygen consumption or cost is not always feasible and is costly. PCI is an alternative for the same. The Physiological Cost Index (PCI), has been used as a simple, indirect measure of oxygen cost during exercise. To assess and compare the Physiological Cost Index in between normal and spastic diplegic children

In conjunction with other medical, surgical, and therapeutic interventions, orthosis carry on to play a significant role in the physical management of children with Cerebral Palsy. Orthosis are intended with one of two primary aims: either to affect the body structure or to assist function, although for children with CP, orthosis are commonly designed to accomplish both of these aims.

But it is important to evaluate if the orthosis affect the energy requirements while walking [6,17].

Cerebral palsied children with dynamic equines deformities can advantage from AFOs for ambulation [18]. There have been many studies related to PCI, to measure energy expenditure of ambulation in normal children or children with ambulation disabilities since its introduction [Butler et al. (1984), Loder & Herring (1987), Graham et al. (2005), Mossberg et al. (1990), Rose et al. (1991), Rose et al. (1990), Rose et al. (1985), Stein et al. (2005)]. Butler et al. (1984) studied 70 normal children to associate speeds, heart rate, and the PCI while walking at self-selected speeds.

This research takes a significant aspect at whether the PCI can be used to amount efficacy of ambulation in normal children and children with cerebral palsy group. The aim of the study is to compare Physiological Cost Index in healthy normal children as against ambulatory spastic diplegic cerebral palsy (with and without orthosis) in the age group 6-18yrs.”

METHODOLOGY
50 community walking spastic diplegic cerebral palsy was screen but according to inclusion criteria only 41 were included. from .The study design is Cross sectional design. material used was Polar watch, B.P. apparatus, Measuring tape, Paper, Pensile, Weighing machine.Ethical approval taken from ethical committee. Thus a convenient sample of 41 ambulatory (community walking) spastic diplegic cerebral palsy children age between 6-18 yrs. children who walks using plastic AFOs i.e. with or without orthosis and assistive devices were selected by purposive sampling technique from cerebral palsy rehabilitation centers around Mumbai & Pune and a comparable normal healthy children age matched were included. This research covered period from first July 2014 to first Dec 2015. Children who had any known cardiovascular or respiratory problems, any associated recent musculoskeletal injury to lower limbsand visual, hearing, cognitive or perceptual impairments were excluded from the study. An informed written consent was taken from the parents. Approval from ethical committee was taken. Basic assessment was done with inclusion of PCI, BMI, Ambulation capacity of the spastic CP and normal children. Then two groups are formed, one normal children and other spastic diplegic CP.
Testing procedure for PCI: Child’s resting heart rate was noted using the polar heart rate monitor was attached around the chest. Formerly recording HR at rest, the participant was settled in silence for about five minutes and then it was noted each minute for the following five minutes. The walking was conducted indoors, in a corridor. Child was asked to walk without the orthosis but with / without walking aid for spastic CP and shoe off for normal children, at their chosen velocities over four consecutive lengths of a 12.5m walkway i.e. total 50m. The time required to walk the distance was recorded. The heart rate at the end of the walk was recorded i.e. pre readings are taken. The child was then allowed to take rest till the heart rate came to the resting level. The same procedure was then repeated with the orthosis for spastic children and shoe on for normal children. Again the heart rate and the time were note down. Speed of walking and heart rate were checked constantly and post readings are taken. Heart rate is affected by speed; the physiological cost index (PCI) with speed of walking and heart rate was calculated for each child.

PCI= HR (walking) – HR (rest)

RESULTS

Statistical analysis was performed using statistical package SPSS 21.0.

• Paired T –test used to determine whether there were differences between with orthosis and without orthosis in cerebral palsy children and shoe on and barefoot in normal children.

• Unpaired T-test or Mann-Whitney Rank Sum Test was used for comparison of differences on PCI in normal children with spastic diplegics.

• PCI correlated with the BMI by Pearson’s correlation test for both group.

• Unpaired T-Test is used to compare the walking speed of normal children with spastic diplegics.

• Out of 82 children 56 were boys and 26 were girls.

Table 1: Comparison of Parameters of Normal with Spastic Diaplegic Children

| PARAMETER | NORMAL CHILDREN | SPASTIC CP DIA-PLEGIC |
|-----------|----------------|----------------------|
| VALUE     | SD             | VALUE                |
| AGE (Yr)  | 8.7±2.12       | 10.04±2.67           |
| HT (M)    | 1.38±0.11      | 1.28±0.25            |
| Wt (kg)   | 33.64±8.22     | 22.48±5.49           |
| BMI (kg/m²) | 17.22±2.63  | 15.69±4.9            |

The table 1- shows that the average weight of the Spastic CP children is less than normal healthy children.

Table 2: Comparison of PCI in normal children with Spastic Diaplegic Children

| PCI               | NORMAL CHILDREN WITHOUT SHOE | NORMAL CHILDREN WITH SHOE ON | SPASTIC CP DIA-PLEGIC WITHOUT ORTHOSIS | SPASTIC CP DIA-PLEGIC WITH ORTHOSIS |
|-------------------|-----------------------------|-----------------------------|----------------------------------------|-------------------------------------|
| HR (REST) beats/ min | 88.9±10.09                  | 88.9±10.09                  | 90.63±9.8                              | 90.63±9.8                           |
| HR (MAX) beats/ min | 94.17±11.12                 | 94.07±10.09                 | 96.34±10.9                             | 94.8±10.55                          |
| TIME (MIN)        | 0.48±0.07                   | 0.48±0.07                   | 1.74±0.77                              | 0.77±1.25                           |
| MEAN VELOCITY (SPEED) m/min | 106.77±17.19             | 107.04±17.17                | 96.46±21.82                            | 51.13±32.49                         |
| PCI beats/m        | 0.05±0.039                  | 0.049±0.036                 | 0.199±0.176                            | 0.104±0.093                         |

The table 2: shows that the resting HR for normal children is 88.9 beats/min and spastic CP is 90.63 beats/min. There is difference found in HR after walking, but if compare with normal the children its same for spastic CP, as they are ambulatory at a community level.

Mean velocity (speed) of normal children is very high than the spastic CP ,as time taken by CP children is more than normal children due to functional impairments. So the value of PCI is less for normal children. PCI value 0.049 beats/m in normal healthy children and 0.104 beats/m in spastic CP.

Table 3: Comparison of PCI among the Children

| Normal children | Spastic Diaplegic Children | Comparison |
|-----------------|----------------------------|------------|
| Paired t test   | Paired t test              | Unpaired t test |
| Normal Child    | With shoe                  | Without Orthosis | With Orthosis | Normal Child | Spastic Diaplegic |
| Mean            | 0.0105                     | 0.1098      | 0.1046       | 0.0105       | 0.1988         |
| Variance        | 0.0015                     | 0.0015      | 0.0007       | 0.0015       | 0.0011         |
| Standard Dev.   | 0.0107                     | 0.1794      | 0.0433       | 0.0187       | 0.1764         |
| N               | 41                         | 41          | 41           | 41           | 41             |
| T               | 1.1455                     | 4.1375      |              | -5.2924      |                |

The table 3: shows that comparison of PCI values in the children without and with shoes showed not significant difference, comparison of PCI values in spastic CP without and with orthosis showed significant difference and comparison of PCI value in normal and spastic CP showed significant difference.
Graph 1: Correlation of PCI with the BMI in normal children.

(by Pearson's correlation test) The graph 1- shows that the value of r is -0.0115. Although technically a negative correlation, the relationship between PCI and BMI variables is only weak in normal children.

Graph 2: Correlation of PCI with the BMI in spastic CP children

(by Pearson's correlation test) The graph 2- shows that the value of r is 0.0114. Although technically a positive correlation, the relationship between PCI and BMI variables is weak in spastic CP.

Table 4: Unpaired T-Test is used to compare the walking speed of normal children with spastic diplegics:

|                | NORMAL CHILDREN | SPASTIC DIAPILEGICS |
|----------------|-----------------|---------------------|
| Mean           | 106.7778        | 51.5698             |
| Variance       | 295.5866        | 1049.3084           |
| Stand. Dev.    | 17.1926         | 32.393              |
| n              | 41              | 41                  |
| t              | 9.6394          |                     |
| Degrees of freedom | 80            |                     |
| Critical value | 1.664           |                     |

The table 4 shows that the calculated t exceeds the critical value (9.6394>1.664), so the means are significantly different, at p ≤ 0.05 ,there is significant difference in the speed of the normal children than spastic CP as they have different gait patterns are seen in spastic CP ,Crouch gait, Genu Recurvatum gait Neutral knee gait (Gage 1991, Perry Antonelli and ford 1975,Suntherland and Cooper 1978,Simon, et al 1978, Perry J. Roberta Shephard 1974)

DISCUSSION

Cerebral Palsy is a neurological condition that affects the muscle tone & co-ordination. In spastic diplegic cerebral palsy mainly the lower limbs are affected causing spasticity of lower limbs, exaggerated deep tendon reflexes, muscular imbalance, etc [3]. Orthotic ambulation is a principal concern in the rehabilitation procedure of spastic diplegic CP, and it is chiefly addressed in energy expenditure and walking speed [5].

Out of 41 CP children 33 boys and 8 girls and in normal 41 group 23 boys and 18 girls participated in study. Normal children age 8.7±2.12 yrs and Spastic Diplegic CP 10.04 ±2.67 yrs. BMI17.22 ±2.63 and 15.69±4.9 (kg/m2) respectively.

Among 41 CP children 17 were using elbow crutch for ambulation, so they assess with the same.(Table no. 2) The children with CP performed doublemechanical work on their COM compare to typicallygrowing children as in both a greater vertical excursion of their COM and a lesser phasic association between their kinetic and potential energies [6]. Olney et al (1987)testified that in children with hemiplegic CP a "poor pattern of exchange between potential and kinetic energy of the HAT (head, arms, torso) segment contributed to high total energy costs."(Table 3) AFOs helps in progress of the gait of an individual patient, but may not be usefulinother children with CP.AFO usage increased a more pendular gait pattern which allow better energy recovery, the amplified work of extended steps (increased energy variation) meant that the work per meter on the COM fixed [6].

The measured modifications in traditional gait parameters of children with CP with AFOs were compared in previous studies. There was increase in stride length with the solid and articulated braces . As in this research, these studies compared barefoot walking to walking in AFOs and shoes. We establish that, there was an increase in walking velocity tendency with AFO use. Previous exploration has been ambiguous with some researchers finding an increase in preferred walking velocity and others finding no change in preferred velocity[17].

There was an abundant pact of change ability in the measured work, with both great rises and falls in the work of individual subjects when wearing orthoses. The AFO prescription could be assisted by calculating the mechanical work during walking. The energy expenditure of ambulation at self-selected speeds in spastic diplegic children was reduced by the use of conventional AFOs. However, each child should be assessed on a single-case basis because of individual differences[6].

Graph 1 &2, Pearson Correlation Coefficient between BMI and the PCI found weak negative relationship between them was observed i.e. r = 0.0114in spastics and r = -0.0115 in normal.

Mahadeva et al. (1953) , they found that in stepping, the energy expenses was straightcomparative to body weight; in walking, the deterioration streak was also linear but did
not pass through the origin. It showed that no significant difference in PCI when compared with the height, sex, age, and race for the individuals. The authors determined that in any physical movement, a large proportion of the energy costs were used to move the body weight and the metabolic cost was directly related to the body weight[20]. (Table 5) speed of walking: Spastic diplegics CP require elevated oxygen/energy consumption during walking as compared to normal individuals with matched speed [8]. In gait, Hip extension is very important in 60% of gait cycle with hip flexion contracture. Part of the limited hip excursion can be compensated by increased pelvic motion and mobility of the lumbosacral joint in spastic diplegic CP. Knee flexion contracture increases requirements of gait (Sutherland and Cooper 1978 and Sutherland 1980)[4]. As with surge in age, the speed rises and walking heart rate declines with resting heart rate also falls. Thus, the PCI value remains same for all ages. The PCI values for children with spastic diplegics considerably higher than that for normal children, so the PCI is a treasured quantitative pointer of the level of handicap[4].

CONCLUSION

This study showed that walking with orthosis in spastic diplegic CP children showed higher costs of energy and slower walking speed compared normal children with age matched. The physiological cost index (PCI) of walking, with orthosis in children with spastic Diplegic cerebral palsy is less as compared to without orthosis i.e. gait is more energy efficient with orthosis. BMI doesn't show any correlation with PCI further study may require.

CLINICAL SIGNIFICANCE: Orthosis helps to decrease the energy expenditure of walking, thus producing an energy efficient gait.

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LIMITATION: Small sample size

REFERENCES

[1] B. Bobath. Abnormal postural reflex activity caused by Brain Lesions. 1976. Churchill Livingstone, Edinburg.

[2] Peter Robson. A neurophysiological basis for the treatment of cerebral palsy. Arch Dis Child. 1981 Jan; 56(1): 80.

[3] J A Fixsen. Orthopedic management in cerebral palsy. Arch Dis Child. 1994;71:396-397

[4] Butler P, Engelbrecht M, Major RE, Tait JH, Stal- lard J, Patrick JH. Physiological cost index of walking for normal children and its use as an indicator of physical handicap. Dev Med Child Neurol. 1984 Oct;26(5):607-12.

[5] Raja K, Joseph B, Benjamin S, Minocha V, Rana B. Physiological cost index in cerebral palsy: its role in evaluating the efficiency of ambulation. JPediatrOrthop. 2007 Mar;27(2):130-6.

[6] Bradford C. Bennett, Shawn D. Russell, and Mark F. Abel. The Effects of Ankle Foot Orthoses on Energy Recovery And Work During Gait In Children With Cerebral Palsy. ClinBiomech (Bristol, Avon). 2012 Mar; 27(3): 287–291.

[7] Ijzerman MJ, Nene AV. Feasibility of the physiological cost index as an outcome measure for the assessment of energy expenditure during walking. Arch Phys Med Rehabilitation. 2002 Dec;83(12):1777-82.

[8] Anna Sofia Delussu, Giovanni Morone, Marco Iosa, Maura Bragoni, Stefano Paolucci, and Marco Trabalesi, Concurrent Validity of Physiological Cost Index in Walking over Ground and during Robotic Training in Subacute Stroke Patients. BioMed Research International Volume 2014 (2014), Article ID 384896, 6 pages

[9] Boyd, Stefania Fatone et al. High- or low-technology measurements of energy expenditure in clinical gait analysis? Dev Med Child Neurol. 1999 Oct;41(10):676-82.

[10] Danielson A, Willén C, Sunnerhagen KS. Measurement of energy cost by the physiological cost index in walking after stroke. Arch Phys Med Rehabil. 2007 Oct;88(10):1298-303.

[11] Bratteby Tollerz LU, Olsson RM, Forslund AH, Nor- rlin SE. Reliability of energy cost calculations in children with cerebral palsy, cystic fibrosis and healthy controls. Acta Paediatr. 2011 Dec;100(12):1616-20.

[12] Chen CN, Hwang AW, Lin SY, Lin YC. Initiation of Movement and Energy Expenditure in Children with Developmental Delay: A Case-Control Study. Phys Ther. 2014 Oct;94(10):1434-42.

[13] Shajan Ajith, Mohamed Faisal Ck et al. Physiological Cost Index (PCI) in Patients with Chronic Obstructive Pulmonary Disease (COPD) Before and After Giving Two Commonly Used Breathing Exercises. International Journal of Current Research and Review. 2011; 3(12):41-48.

[14] Arazpour M, Bani MA, Hutchins SW, Jones RK. The physiological cost index of walking with mechanical and powered gait orthosis in patients with spinal cord injury. Spinal Cord. 2013 May;51(5):356-9.

[15] Leung AK, Wong AF, Wong EC, Hutchins SW. The Physiological Cost Index of walking with an isocentric reciprocating gait orthosis among patients with T(12) - L(1) spinal cord injury. Prosthet Orthot Int. 2009 Mar;33(1):61-8.

[16] Teuta Osmani Vllasolli, Nikola Orovecanec, Beti Zafi rova, Blerim Krasniqi, Aridana Murtezani, Valbona Krasniqi, and Bukurije Rama. Physiological Cost Index and Comfort Walking Speed in Two Level Lower Limb Amputees Having No Vascular Disease. Acta Inform Med. 2015 Feb; 23(1): 12–17.

[17] K. A. Mossberg, K. A. Linton, K. Friske. Ankle-foot orthoses: Effect on energy expenditure of gait in spastic diplegic children, Arch Phys Med Rehabil. 1990 Jun;71(7):490-4.
[18] Erbil Dursun, NigarDursun, DuyguAlican. Ankle-foot orthoses: effect on gait in children with cerebral palsy. Disability And Rehabilitation. 2002;24(7):345-347

[19] Olney SJ, Costigan PA, Hedden DM. Mechanical Energy Patterns in Gait of Cerebral-Palsied Children with Hemiplegia. Physical Therapy. 1987; 67(9):1348–1354.

[20] Mahadeva, K., Passmore, R., & Woolf, B. Individual variations in the metabolic cost of standardized exercises: the effects of food, age, sex and race. J Physiol. 1953 Aug 28; 121(2): 225–231.

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