ORIGINAL ARTICLE

IJPHY

COMPARISON BETWEEN PHYSIOLOGICAL COST INDEX IN HEALTHY NORMAL CHILDREN AS AGAINST AMBULATORY SPASTIC DIPLEGIC CEREBRAL PALSY (WITH AND WITHOUT ORTHOSIS) IN THE AGE GROUP 6 TO 18 YEARS

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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 diaplegic. Also we aimed to analyze whether BMIhad impact on energy cost.

Method: 41 normal children and 41 community walking spastic diaplegic aged between 6 to 18 yrs. were assessed to compare the PCI. Speed of walking and heart rate were checked constantlyboth barefoot and in shoes in normal children and with and without conventional AFO in children with spastic diaplegic 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 ±0.039beats/meter. The PCI for children with pathological gait i.e. spastic diaplegic without orthosis and with orthosis is 0.199 ±0.176 and 0.104± 0.093beats/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 showany correlation with PCI further study may require.

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

Received 21st May 2016, revised 17th June 2016, accepted 04th August 2016

10.15621/ijphy/2016/v3i4/111042

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INTRODUCTION

Cerebralpalsy 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 preganacy [1,2].

CP is the one of the commonest movement disorderseen 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 CPhave 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 capacityof spasticdiplegic-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_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_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 forsubjects with orthosis withobjective measurement.

We started this study aiming to objectively compare the PCIand walking speed of normal children with ambulatory spastic diaplegic. 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 ansignificant 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 asignificantaspect at whether the PCI can be used to amountefficacy of ambulation in normal children and children with cerebral palsy group. The aim of the studi 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 41ambulatory (community walking) spastic diaplegic cerebral palsy children age between 6-18 yrs. children who walks using plastic AFOs i.e. with or without orthosis and assistive deviceswere 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 Dec2015.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 orthosisbutwith / 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.

$$PCI = \frac{HR\ (walking) - HR\ (rest)}{Walking\ speed}$$

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 incerebral 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 diplegic CP
- 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 children56 were boys and 26were girls.

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

PARAMETER	NORMAL CHILDREN		SPASTIC CP DIAPLEGIC	
	VALUE	SD	VALUE	SD
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:

PARAMETER	NORMAL CHILDREN WITHOUT SHOE		NORMAL CHILDREN WITH SHOE ON		SPASTIC CP DIAPLEGIC WITHOUT ORTHOSIS		SPASTIC CP DIAPLEGIC WITH ORTHOSIS	
	VALUE	SD	VALUE	SD	VALUE	SD	VALUE	SD
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	1.25	±0.58
MEAN VELOCITY (SPEED) m/min	106.77	±17.19	107.04	±17.17	36.46	±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 90.63beats/min.There is difference found in HR after walking,but if compare with normal the children its same for spastic CP, as they areambulatory at a community level.

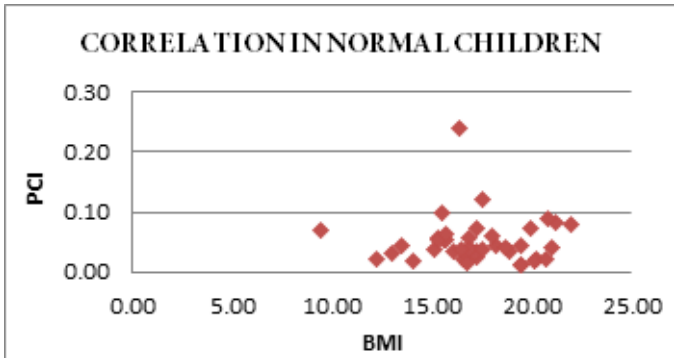
Mean velocity (speed) of normal children is very high than the spastic CP ,as time taken by CP children is more than normal children due to functional impairments.so the value of PCI is less for normal children. PCI value 0.049 beats/m in normal healthy children and 0.104 beats/m in spastic CP.

Table3: Comparison of PCI among the Children

Paired t test			Paired t test			Unpaired t test		
Normal children			Spastic Diaplegic Children			Comparison		
	Without shoe	With shoe		Without Orthosis	With Orthosis		Normal Children	Spastic Diaplegic
Mean	0.0505	0.0498	Mean	0.1998	0.1046	Mean	0.0505	0.1998
Variance	0.0015	0.0013	Variance	0.0311	0.0087	Variance	0.0015	0.0311
Stand. Dev.	0.0387	0.0361	Stand. Dev.	0.1764	0.0933	Stand. Dev.	0.0387	0.1764
N	41	41	n	41	41	N	41	41
T	1.1155		t	4.1575		T	-5.2924	
degrees of freedom	40		degrees of freedom	40		degrees of freedom	80	
critical value	1.684		critical value	2.021		critical value	1.99	
Thecalculated't' is -1.1155, at $p \leq 0.05$.*means are not* significantly different.			The calculated't' exceeds, at $p \leq 0.05$.so the means are significantly different.			The calculated't'exceeds, at $p \leq 0.05$.so the means are significantly different.		

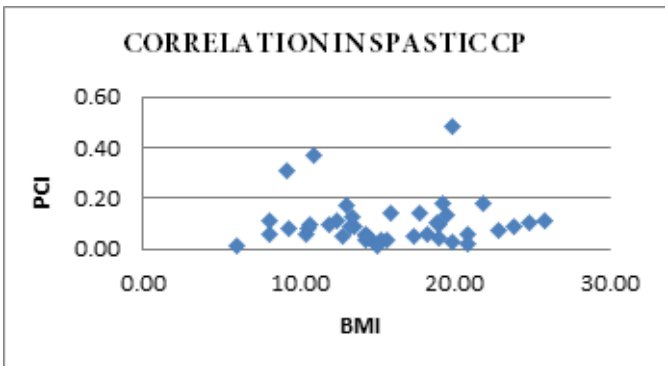
The table 3: shows that comparison of PCI values in the children without and with shoes showed not significant difference, comparison of PCI values in spastic CP without and with orthosis showed significant difference and comparison of PCI value in normal and spastic CP showed significant difference.

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 DIAPLEGICS
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 $p \leq 0.05$,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 diaplegic CP, and it is chiefly addressed in energy expenditure and walking speed [5].

Out of 41 CP children 33boys 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 Diaplegic 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 progressof the gait of an individual patient, but may not be usefulinother children with CP.AFO usageindorsed a more pendular gait pattern which allowbetter 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 tendencywith 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 greatrises 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 = -0.0115in normal.

Mahadeva et al. (1953) ,they found that in stepping, the energy expenses was straightcomparative to body weight; in walking, the deteriorationstreak 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 costswere 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 andwalking 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 diplegicsis considerablyhigher 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 normalchildren withage 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.

ACKNOWLEDGEMENT: Thanks to SAI SEVA DHAM and APANG VIDYALAY children for participating in the study.

LIMITATION: Small sample size

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Citation
Bhise, S., Bane, J., Parab, S., & Ghodey, S. (2016). COMPARISON BETWEEN PHYSIOLOGICAL COST INDEX IN HEALTHY NORMAL CHILDREN AS AGAINST AMBULATORY SPASTIC DIPLEGIC CEREBRAL PALSY (WITH AND WITHOUT ORTHOSIS) IN THE AGE GROUP 6 TO 18 YEARS. *International Journal of Physiotherapy,* 3(4), 395-400.