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SPATIO-TEMPORAL GAIT VARIABLES OF CHILDREN WITH CEREBRAL PALSY UNDERGOING ELETROSTIMULATION IN THE ANTERIOR TIBIAL MUSCLE

JERÔNIMO BP [1], SILVEIRA JA [1], BORGES MBS [1], DINI PD [2] & DAVID AC [2]

[1] Department of Physical therapy, Catholic University of Brasilia, Taguatinga, DF - Brazil

[2] School of Physical Education, University of Brasilia, Brasilia, DF – Brazil

Correspondence to: Maria Beatriz Silva e Borges, SQS 404, Bloco T, Apto 202, Asa Sul, CEP 70238-200, Brasília, DF – Brasil, e-mail: mariab@ucb.br

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ABSTRACT

Objective: This study had the objective of describing spatiotemporal gait variables of four to five-year-old children with spastic hemiplegic cerebral palsy, before and after sessions of electrostimulation of the anterior tibial muscle on the paralyzed side. Method: Five children underwent 12 sessions of electrostimulation (three times a week). To collect biomechanical data, the gait was analyzed using the Peak Motus system, version 7.0, with two S-VHS video cameras with an acquisition rate of 60 Hz. Three-dimensional reconstruction of the movements was performed using the direct linear transformation (DLT) method. Results: Following the intervention, all the children presented smaller differences in step length between the paralyzed and non-paralyzed sides ($p= 0.009$). Four children presented increased cycle amplitude. Two children presented increased cadence, speed and single support time on the paralyzed side. Thus, it was found that there was an improvement in gait symmetry in relation to the step lengths seen before and after the intervention, although the increase in the spatiotemporal variables did not occur in the same way for all the children. Conclusion: Despite the difficulties in defining larger and more homogeneous samples for studies of this type, the present data suggest the need for identification of and greater control over the variables that affect gait and its treatment among children with cerebral palsy.

Key words: electrostimulation; cerebral palsy; hemiplegia; children; gait.

INTRODUCTION

Cerebral palsy (CP), defined as a chronic non-progressive childhood encefalopathy, is a movement and postural disorder provoked by an injury of the immature brain[1]. Hemiplegia is characterized by a motor deficit and unilateral spasticity, affecting the upper and lower limbs counter-lateral to the affected hemi-brain. The hemiplegic child produces movements preferentially using the normal hemi-body, and demonstrates body alignment deficits, which make weight transfer difficult on the affected side[2,3]. The muscle tonus imbalance interferes with motor development, resulting in a spastic musculature shortening, and weakness of the non-spastic antagonist musculature[4,5].

Neuromuscular electrostimulation is a therapeutic technique that has the capacity to produce muscular contractions. Many studies on electrostimulation have been conducted with adults, showing effectiveness on the treatment of disuse atrophy, as well on the maintenance of the range of movement and muscular reeducation[5,6,7,8,9]. The neurophysiological reasons for the effectiveness of electrical stimulation over the antagonist of the spastic muscle may reside on the principle of reciprocal inhibition, that is, when stimulating a group of flexors, an immediate reduction of the extensors' tonus occurs. From this reduction, voluntary movements that were inhibited may be obtained. The repetition of these movements yields, by a feedback mechanism, new motor patterns of the central nervous system (CNS), which may be used for functional objectives[2].

This technique has been employed also as a form of treatment to enhance the gait in children with CP. However, the retrieved studies, which investigated the effects of electrostimulation on the gait of children, have usually used a small sample of children over a wide age range[8,10,11,12,13]. Many times, despite the subjects having received the same clinical diagnosis, they demonstrate distinct levels of motor compromising, and clinical history. This heterogeneity has made generalizations difficult[12], and contradictory results have been found[13].

The most often used parameters to verify the effectiveness of electrostimulation of improvements of children's gait have been the curves, which originated from angular kinematics and dynamics. However, many authors have shown that the spatio-temporal parameters bring important information about the gait in children with cerebral palsy[13,14]. These parameters are easily calculable from the videography, without the necessity of determination of the joint centers for the calculation of joint angles and moments.

The objective of this study was to describe the spatio-temporal gait variables in a group of children aged between 4 and 5 years old, with spastic hemiplagia CP, who had lesions caused by complications which previously occurred to the acquisition of independent gait, before and after 12 sessions of electrostimulation on the anterior tibial muscle associated with conventional treatment.

METHODOLOGY

The sample was selected from the patients who attended to the Neuropediatric Sector of the Clinical School of the Catholic University of Brasilia, and who had a clinical diagnosis of cerebral palsy (CP) of the spastic hemiplegia type. All subjects were capable of independent gait. Children who had use over the last six months any spasm-reducing medicaments were excluded, as well those children who could not complete the proposed experimental protocol due to cognitive deficits. From 10 selected children, two were not authorized by the parents to take part of this study, and three abandoned the research. Therefore, five children (three girls and two boys), aged between 4 and 5 years old, who had their degree of spasticity assessed using the Ashworth Scale[15] (Table 1) participated in this study. This study was approved by the Research Ethics Committee of the Catholic University of Brasilian protocol nº 114/2005, and the adults responsible for the children signed the free and clear terms of consent.

Table 1. Subjects' Characteristics.

Subjects	Age (years)	Gender	PC Cause	Plegic Side	Spasticity level*
1	5	F	Hypoxia/	Left	1
2	4	M	CVA**	Left	2
3	5	F	Birth	Left	1
4	5	F	Premature Birth	Left	3
5	4	M	Premature Birth	Left	3

*Ashworth Scale[15]; ** Cerebral Vascular Accident.

Each child was submitted to a gait analysis evaluation two days before and two days after the 12 week intervention in the Biomechanics Laboratory from the School of Physical Education of the University of Brasilia. For image recording, the 7.0 version Peak Motus system was used, with two video cameras with incoming rate of 60 Hz. For three-dimensional reconstruction, the Direct Linear Transformation (DLT) method was used and, in order to buffer the data, the Butterworth filter was applied with a cutting frequency of 5 Hz. The reflective markers were bilaterally positioned at the greater trochanter region of the femur's, lateral face of the joint line of the knee, the lateral malleolus, the insertion of the heel tendon and above the head of the 2º metatarsus. For the calculation of the spatio-temporal parameters, only the marks placed over the right and left heel tendons were used.

Four attempts with each child were recorded, with gait at an auto-selected velocity, for a 10 m long route. Only one attempt was selected for analysis, for not all children had valid attempts, and the one that had selected was considered representative of the rest. This procedure is commonly used in gait analysis, however, it does not allow verifying intra-subject variability[16]. The gait parameters selected for analysis were as follows: step length, stride length, velocity, cadence, single support time, total support time, and total stride time. The determination of the gait events for calculation of these parameters was performed according to the literature[17]. Total single support time, and total support time were calculated in relation to total stride time. Step symmetry was calculated by the difference between the length of the non-plegic step and the length of the plegic step.

After the first gait analysis, a treatment program with 12 sessions of electrostimulation on the anterior tibial muscle of the plegic side was initiated, as an additional therapy to the sessions of conventional physical therapy. The FES VIF DUAL 995 Quark device, with a biphasic, symmetric current, at a pulse frequency of 40 Hz, and pulse width of 250 ms was used for electrostimulation. The ON – OFF relation of the stimulation cycles was of 1/2 (TON < 6 seconds and TOFF < 12 seconds). The current intensity was determined for each patient according to the visually observed range of motion and the child's tolerance[12,13].

Electrostimulation was performed with the children seated on the examination table, with the foot relaxed in 25 minute sessions three times a week on alternate days, over four weeks. One of the 2X4 dimension silicone electrodes was positioned on the anterior tibial muscle motor point of the plegic leg, and the other 2 cm below (Figure 1). The children were not solicited to perform torso-flexion during the passage of the current, since not all of them could perform this movement voluntarily, and this would make the data inconsistent.

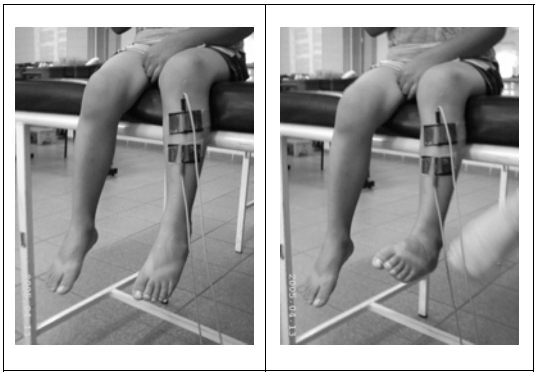

Figure 1. Eletrical stimulation technique and eletrodes position.

In order to verify if there were statistically significant differences for the spatio-temporal variable before and after the intervention, the non-parametric Mann-Whitney U test was used with a significance level of $p < 0.01$.

RESULTS

After electrostimulation, improvements in the step length symmetry were observed for all participants, as represented by gait symmetry ($p < 0.009$). For the other variables, no statistically significant differences were found (Table 2). However, an increase of the stride length for four out of five children from this sample was observed.

When the results were analyzed individually, the subjects 3 and 4 demonstrated the best results with increases in velocity, cadence and step length being observed (Table 2), also, increases of the single support time of the plegic limb and a decrease of the total stride time (Table 3).

The greater gait symmetry occurred because of many strategies: increases of the stride length on the plegic side (subjects 1 and 2), and/or decreases of the step of the countra-lateral limb (subjects 1 and 5). For subject 3, an increase of the stride length for both sides occurred, incurring then, an increase of velocity. There was, also, a velocity increase for subject 4, who showed a greater step length on the non-plegic limb.

Table 2. Gait spatio-temporal variables before and after treatment.

Subject	Trial	Non-plegic step length (m)	Plegic step length (m)	Step symmetry (m)	Stride length (m)	Velocity (m/s)	Cadence (step/min)
1	before	0.429	0.383	0.046	0.812	1.037	153.20
	after	0.405	0.422	0.017	0.827	0.871	126.32
2	before	0.337	0.276	0.061	0.613	0.817	160.00
	after	0.337	0.353	0.016	0.690	0.828	144.01
3	before	0.347	0.261	0.086	0.608	0.553	109.09
	after	0.393	0.359	0.034	0.752	0.820	130.92
4	before	0.305	0.356	0.051	0.661	0.559	101.41
	after	0.364	0.338	0.026	0.702	0.669	114.29
5	before	0.348	0.404	0.056	0.752	0.981	156.54
	after	0.249	0.285	0.036	0.534	0.593	133.33
		$p < 0.83$	$p < 0.83$	$p < 0.009$	$p < 0.67$	$p < 1.0$	$p < 0.60$

Table 3. Relative and absolute temporal gait variables before and after treatment.

Subject	Trial	Single support plegic side (%)	Single support non-plegic side (%)	Support time plegic side (%)	Stride time (s)
1	before	36.17	42.59	57.44	0.783
	after	36.84	36.87	63.15	0.950
2	before	35.55	40.04	59.97	0.750
	after	31.99	40.03	59.98	0.833
3	before	33.33	33.36	66.65	1.100
	after	34.54	41.85	58.17	0.917
4	before	35.21	35.24	64.78	0.767
	after	39.68	36.53	63.48	0.900
5	before	32.61	43.52	56.51	1.183
	after	31.48	38.92	61.10	1.050
		$p < 0.91$	$p < 0.75$	$p < 0.75$	$p < 0.60$

Subjects 1 and 2 showed increases in the length of the plegic limb, however, there were cadence decreases. Subject 1 demonstrated velocity decreases, but kept the same single support time for the plegic limb. Contrarily, subject 2 kept the same velocity, but showed a decrease in the time of single leg support on the plegic side.

Subject 5 revealed smaller values in all the analyzed variables, possibly explained by increase on the total stride time, which demonstrated a slower velocity in the attempt analyzed after intervention. However, symmetry of his gait also had improvements after the intervention.

DISCUSSION

Some authors[18] consider that there is no absolute method of gait assessment for hemi-plegic patients, however, the degree of motor recovery would correspond to improvement in the spatio-temporal variables. Increases of gait efficiency are related to increases in velocity, and they observed that bi-plegic children use increases in cadence as their main strategy to increase velocity[13]. In this study, children who had an increase in velocity also increased their cadence.

Healthy children demonstrate higher spatio-temporal parameters when compared to children with CP. These present smaller step length when compared to healthy children[13,19]. Average values found for stride length, cadence, and velocity in four-years-old healthy children were of 0.78 m, 152 steps/min, and 0.99 m/s, respectively[20]. In this study, stride length increased in 4 out of 5 analyzed subjects after intervention, reaching values closer to those obtained for healthy children of the same age.

In the present study, all children showed lower values in the differences between the step lengths of the plegic and non-plegic sides, showing higher gait symmetry, after the intervention. Several times this fact occurred due to the increase of the plegic lateral step length (subjects 1 and 2), showing better balance and sustaining capacity[3,21], or decreases of the countra-lateral limb. The step symmetry may be an important indicator of gait efficiency, together with the single support time[3,21]. In this study, two children had consistent results with increases in cadence, velocity, step length and single support time of the plegic side and decrease of the total stride time.

One of the most important parameters in gait, related to balance, is the time of single leg support[21]. Hemiplegic children show a tendency to use more the non-plegic limb during the support phase at gait[22]. Increases in the time of single leg support time of the plegic side shows longer sustaining capacity of the bodyweight on the plegic limb, showing the benefits of an additional program of muscular strengthening for these children[23]. The increases in this temporal variable are in accordance with the statements of some authors[5,6] that, by using electrostimulation with under-threshold motor intensity, increases of consciousness of the involved extremity are observed, improving in this way their functioning. Electrostimulation also promotes cutaneous feedback and proprioception, thus improving, balance[8].

In this study, the relationships between the variables did not always show the same tendencies for all children. However, an important fact was the statistically significant difference for gait symmetry, which suggests higher movement efficiency[12]. These increases in symmetry could mean that electrostimulation, together with conventional therapy, allowed the children to develop better movement coordination. However, there is no way to separate electrostimulation effects and those caused by conventional treatment to which the children were being submitted.

There was some difficulty in comparing between hemiplegic children because, despite all of them showing only half of their body being affected, the cortical area affected may occur distinctively, thus justifying the variety of measured patterns. Other investigators[24] also had difficulties in creating a satisfactory classification system to separate children into more homogeneous groups. In the present study, we tried to restrict the sample age range in a way to lower the number of intervening variables and, with this, to have more confidence in the inferences.

CONCLUSIONS

The results showed that there was an improvement in gait symmetry after 12 sessions of the electrostimulation treatment on the anterior tibial muscle, associated with conventional treatment. This symmetry improvement was obtained through different strategies of plegic limb step length increasing and/or non-plegic limb step decreasing. Two children obtained increases in cadence and velocity, and one maintained the same velocity and increased cadence. Although gait velocity and cadence increase are expected results after treatment, symmetry may be an important factor.

Another essential dimension was that the stride length increased in four out of the five subjects studied after the intervention, thus approximating to the values encountered for healthy children of the same age. These data may allow future comparisons in the assessment of different forms of intervention related to gait in children with cerebral palsy. These results suggest the necessity for larger and more homogeneous samples regarding age and degrees of commitment, as well as the need to differ the effects obtained by conventional treatments, and those obtained by electrostimulation with experimental and control groups.

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