

How does applying of one or two orthoses influence gait parameters of children with hemiplegia?

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The aim of this study was to evaluate how wearing one or two orthoses influence the gait parameters in children with hemiplegia. Four children with hemiplegic cerebral palsy participated in the study. Patients were from 3 to 7 years old; one girl and three boys; one patient with right side hemiplegia, three patients with left side hemiplegia. Patients underwent the VICON MX system gait analysis three times (sessions): one with bare feet, the other two with shoes and orthoses: one with orthoses used unilaterally on palsied limb, one with orthoses used bilaterally. The following gait parameters were analyzed: velocity, cadence, pelvis tilt, range of pelvic movement in sagittal plane, separately for affected and non-affected side: step length, stance time (as a percentage of the gait cycle), range of hip movement in sagittal plane, knee flexion at initial contact, maximum knee flexion in swing phase. Results of the study showed which and how many gait parameters changed while wearing one in comparison with two orthoses. The results did not give a clear indication which condition is better: wearing one or two orthoses, however they suggest that when the orthotic devices are considered for patients with hemiplegic cerebral palsy, the objective, instrumented gait analysis can be used to take the best decision whether one or two orthoses should be prescribed.

Key words: cerebral palsy, hemiplegia, orthoses, VICON MX system gait analysis, gait parameters

1. Introduction

Cerebral Palsy is an impairment of posture and motor control caused by non-progressive damage to the developing brain [3]. Such features as lack of motor control, abnormal biomechanical alignment of body segments, impaired timing of muscle activation, impaired normal agonist-antagonist muscle balance, lack of power generation, and balance disorder later lead to different musculoskeletal system deformities and abnormal motor control [3], [19].

Patients with unilateral CP constitute about 30% of all CP children, most of them with spastic form of hemiplegia [17]. There are two forms of unilateral cerebral palsy due to severity of the disorder: hemiparetic and hemiplegic cerebral palsy. Hemiplegic CP is more severe and it reveals itself by total paralysis of the

affected side of the body and hemiparetic CP involves mild paralysis and/or muscle weakness [1].

The aim of treatment of CP children is to enable culturally adequate activities and participation by promoting efficient movement, limiting deformity, reducing pain, and employing cognitive and/or behavioral strategies [18]. Treatment of hemiparetic or hemiplegic cerebral palsy includes, among others, physical and occupational therapy, orthopedic surgery, splints, botulinum toxin, seizure medication if needed, and sensory integration. The treatment of CP patients should improve body functions, structures, activity and level of participation in everyday life [23], [24].

Orthotic is an important tool in treatment of children with cerebral palsy. According to ISPO (International Society of Prosthetics and Orthotics), there are several aims of the use of orthotics in CP children: to correct/prevent limb deformities, to provide the better

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Received: December 11th, 2019

Accepted for publication: May 21st, 2019

base of support during standing and walking, to facilitate rehabilitation, and to improve efficacy of gait. This latter aim is achieved by restoring prerequisites necessary for gait through altering the ground reaction forces acting on the body. Their use also can diminish the energy expenditure [16], [25].

By applying orthoses for children with unilateral CP we can influence skeletal structures (abnormal bony structure/growth, joint alignment, joint deformity, range of motion of a joint, ligamentous laxity, ligamentous shortening), muscles and tendons (muscle/tendon length, length of muscle to tendon ratio, “extensibilité” of muscle belly, muscle tone and strength, selectivity and timing), developmental maturation and motor learning and functional objectives (sitting, standing, position transfers, walking, arm and hand function in sitting and standing) [7].

Effective orthotic intervention should provide three-dimensional control of the foot and ankle, and simultaneously it must provide three-dimensional support for weak/paralyzed/spastic muscles [4], [21].

There is no agreed standard of prescription of orthoses for the hemiplegic cerebral palsy children. The two factors should be considered: type of orthosis, and use unilaterally or bilaterally. There are studies in which the influence of different types of orthotic devices is evaluated [2], [10], but no studies in which use for both or only palsied limb is assessed. In some studies the orthosis was used only for palsied limb [9], [22], in some on both limbs [2], [10].

The aim of this preliminary study was to answer the question how applying of one or two orthoses influences gait parameters of children with hemiplegia and whether an instrumented gait analysis is suitable for the decision making about applying one or two orthoses for children with hemiplegia.

2. Material and methods

Patients

Four patients with hemiplegic cerebral palsy participated in the study. Patients were from 3 to 7 years old; one girl and three boys; one patient had right side hemiplegia, three patients – left side hemiplegia. One patient had GMFCS level 2, three – level 1. The summary of the patients’ group is presented in Table 1. All 4 patients had orthoses on both limbs prescribed by doctors and they have been wearing them for at least 1 year. All 4 patients were treated in the same hospital and underwent NDT Bobath therapy. Two of them (patients number 3 and 4) underwent earlier the

botulinum toxin therapy (at least 8 months before the study). None of them was submitted to any surgical operation.

Table 1. Age and side of palsy of the patients who participated in the study

Patient	Age	Side of palsy	Orthoses
1	5	left	prefabricated Cascade DAFO JumpStart Kangaroo
2	3	right	custom-made Cascade DAFO Tami 2 with Tamarack hinge
3	5	left	custom-made Cascade DAFO 3.5
4	7	left	custom-made solid AFO VIGO

Patient number 1 – left hemiplegia, prefabricated Cascade DAFO JumpStart Kangaroo.

Preemie 33 Hbd, weight 1970 g, left eye amblyopia, MRI (2014) – PVL

Patient number 2 – right hemiplegia, custom-made Cascade DAFO Tami 2 with Tamarack hinge.

Preemie 26 Hbd, the third one from triplets, weight 1030 g, length 37 cm, IRDS grade 4, IVH 4 grade congenital bronchiolitis, moderate BRD, ventriculomegaly EI on right side 0.41; EI on the left side 0.77.

Patient number 3 – left hemiplegia, custom-made Cascade DAFO 3.5.

Preemie 32 Hbd, cc after mother’s car accident, perinatal clavicle fracture, IRDS grade 2, cranial ultrasound – massive ICH in the right parietal lobe and IVH on both sides, EI – 0.48.

Patient number 4 – left hemiplegia, custom-made solid AFO VIGO.

41 Hbd, weight 3780 g, TAPVD heart defect, ASD grade 2, after heart operation ICH in the right brain hemisphere, in TC – decreased volume of the right brain hemisphere.

Inclusion/exclusion criteria

To our study included were patients with CP hemiplegia (GMFCS level at least 2), who were wearing 2 orthoses for minimum 1 year prescribed by their leading physician. Exclusion criteria were: GMFCS level below 2, moderate or severe mental retardation, bad physical condition in the time of the gait analysis session such as flu, cold, injury or any other disease influencing child’s performance.

Methods

Patients underwent the instrumented gait analysis three times (sessions): one with bare feet, the other two with shoes and orthoses: one with orthosis used

unilaterally on palsied limb, one with orthoses used bilaterally.

All patients wore orthoses prescribed by doctors on both limbs and have been using them for at least 1 year. The time space between gait analyses sessions with 2 orthoses vs. 1 orthosis were designed in such way to give the patients time to adjust to changed biomechanical conditions. After the first two gait analyses (bare feet and with 2 orthoses) all the patient got minimum 4 weeks' time to become accustomed to walk with 1 orthosis and after minimum 4 weeks gait analysis with 1 orthosis was performed.

For gait analysis a 12-camera VICON MX system was used, with Nexus software for capturing and processing the data and Polygon software for preparing the report. During each session, six trials were captured. The Plug-In-Gait model and marker set were used. For the comparisons the averaged data from each session was used. The spatio-temporal data were normalized to sex and age reference. As the group was very small, no statistical analysis was used. The following gait parameters were used for the qualitative analysis: velocity, cadence, pelvis tilt, range of pelvic movement in sagittal plane, separately for affected and nonaffected side: step length, stance time (as per cent of the gait cycle), range of hip movement in sag-

ittal plane, knee flexion at initial contact, maximum knee flexion in swing phase. The kinematic parameters regarding the ankle joints and feet were discarded, as these parameters were more prone to errors while walking with shoes and orthoses.

3. Results

Table 2 presents the results of the gait parameters of the patients who participated in the study in three conditions: walking barefoot, walking with one orthosis on palsied limb, and walking with two orthoses.

In Table 3 the evaluation of the influence of orthoses on the selected for the analysis gait parameters is presented. This influence was described as: the parameter was better while walking in unilateral orthosis ("1"), the parameter was better while walking with bilateral orthoses ("2"), or the influence was equal ("eq").

Table 4 summarizes the number of parameters in which no difference occurred, number of parameters which were better while walking with one orthosis, and number of parameters which were better while walking in two orthoses.

Table 2. The results from the instrumented gait analysis

Barefoot																
Patient	Velocity	Cadence	Stance na	Stance a	Step length na**	Step length a**	Pelvis sag	Pelvis sag range	Pelvis fron range	Pelvis trans range	Hip sag na	Hip sag a	Knee IC na	Knee IC a	Knee swing na	Knee swing a
1	73	88	69.5	58.0	0.32	0.29	3	5	3	8	42	34	16	8	61	53
2	106	104	65.3	58.0	0.36	0.31	5	3	5	15	42	44	2	17	68	58
3	82	88	66.9	60.5	0.35	0.38	7	10	5	15	46	31	23	22	55	47
4	81	86	63.7	57.5	0.49	0.49	12	10	10	18	51	39	8	7	60	54
1 orthosis																
Patient	Velocity	Cadence	Stance na	Stance a	Step length na	Step length a	Pelvis sag	Pelvis sag range	Pelvis fron range	Pelvis trans range	Hip sag na	Hip sag a	Knee IC na	Knee IC a	Knee swing na	Knee swing a
1	85	81	63.4	60.0	0.39	0.39	14	5	4	6	57	56	13	21	59	47
2	87	87	64.8	62.2	0.36	0.33	8	4	5	10	40	46	-11	9	45	41
3	94	94	67.1	62.9	0.51	0.34	7	12	5	10	51	30	6	24	70	52
4	82	82	63.7	55.9	0.53	0.52	12	6	8	14	51	39	-1	5	58	29
2 orthoses																
Patient	Velocity	Cadence	Stance na	Stance a	Step length na	Step length a	Pelvis sag	Pelvis sag range	Pelvis fron range	Pelvis trans range	Hip sag na	Hip sag a	Knee IC na	Knee IC a	Knee swing na	Knee swing a
1	75	80	62.0	62.1	0.40	0.32	4	5	4	10	51	47	15	16	60	47
2	100	87	63.9	60.1	0.42	0.34	12	9	5	20	55	42	3	20	61	52
3	82	79	67.7	60.1	0.42	0.40	10	10	7	15	52	37	14	26	68	53
4	92	84	60.6	55.2	0.56	0.56	14	8	8	20	45	46	12	11	60	34

Velocity and cadence were normalized to sex and age reference, stance phase was normalized to per cent of gait cycle, step length was given in meters, kinematic parameters in degrees. Symbols: sag – sagittal, na – non-affected side, a – affected (palsied) side, IC – initial contact.

Table 3. The summary of the influence of the orthoses of the analysed gait parameters

Patient	Velocity	Cadence	Stance na	Stance a	Step length na	Step length a	Pelvis sagittal	Pelvis sag range	Hip sag na	Hip sag a	Knee IC na	Knee IC a	Knee swing na	Knee swing a
1	1	eq	2	1	eq	1	1	eq	2	1	2	2	eq	eq
2	2	eq	2	2	2	eq	2	1	1	1	2	eq	2	2
3	eq	1	1	2	eq	2	2	eq	eq	2	1	eq	eq	eq
4	2	2	2	1	eq	2	eq	eq	1	2	1	1	eq	2

Symbols: sag – sagittal, na – non affected side, a – affected (palsied) side, IC – initial contact, 1 – better parameter while walking with one orthosis, 2 – better parameter while walking with two orthoses, eq – no difference between walking with one or two orthoses.

Table 4. Number of parameters in which no difference between two conditions occurred, which were better while walking with one orthosis, and which were better while walking with two orthoses

Patient	eq	One orthosis	Two orthoses
1	5	5	4
2	3	3	8
3	7	3	4
4	4	4	6

4. Discussion

The aim of this study was to evaluate how wearing orthoses (either one on affected limb or two on both limbs) change the gait parameters in children with hemiplegia. There is no agreed standard of prescription of orthoses for the hemiplegic cerebral palsy children, and one of the factors which is still not resolved is whether hemiplegic cerebral palsy children should wear one orthosis on palsied limb, or two orthoses on both limbs, especially when an improvement of the efficiency of gait is considered as the aim of their prescription [2], [9], [15], [17], [22], [26]. To improve the gait efficiency, parameters such as (after Gage [8]): stability of the supporting leg during stance phase, clearance of the foot from the ground during swing phase, prepositioning of the limb at the end of swing phase to enable proper foot contact, a step length and conservation of energy expenditure through reduced excursion of the center of mass of the body should be improved. That is why the chosen parameters (velocity, cadence, length of the stance phase, step length, pelvis position and its ROM in sagittal, frontal and transverse planes, hip motion in sagittal plane, knee position at initial contact phase, and knee position in swing phase) were measured and evaluated in our study. Stance and some parameters

for hip and knee were measured for both the affected and no affected side. Especially the dependence between wearing 1 or 2 orthoses and the pelvis position and movement seemed to be very important, because of the influence of the pelvis position on the spine, postural asymmetry and possible development of scoliosis while the child is growing [5], [6], [11], [13], [14], [20].

The results obtained in this study, however, did not give a clear indication which condition (wearing 1 or 2 orthoses) is better and, moreover, in all patients some gait parameters changed similarly in both conditions. Just in one patient (patient No. 2) we observed significant difference between wearing 1 and 2 orthoses in favor of walking with 2 orthoses. In this patient, eleven parameters out of 18 were better while walking with 2 orthoses and those were: pelvis position in all planes (sagittal, frontal and transverse), velocity, cadence, stance both on affected (a) and non-affected side (na), as well as knee position at initial contact (non-affected) and swing phase (both limbs). While walking with one orthosis on the palsied limb, a strong knee hyperextension in the non-affected limb at initial contact appeared, which disappeared while walking with 2 orthoses.

In patients no. 1 and 3 the results indicated similar influence of the two conditions on gait parameters. Half of the observed parameters did not change at all regardless of wearing 1 or 2 orthoses: in patient no. 2 eight parameters out of 18 remained the same and in patient no. 3 – nine parameters out of 18. The rest of the parameters changed equally in favor of wearing 1 orthosis (5 parameters in patient no 1 and 5 parameters in patient no. 2) or in favor of wearing 2 orthoses (5 parameters in patient no. 1 and 4 parameters in patient no. 2). In patient no. 4 six parameters did not change at all and equally 6 parameters each changed in favor of walking with 1 orthosis and of walking with 2 orthoses.

In this preliminary study, the results concerning one patient (no. 2) out of four showed clearly which

treatment (1 or 2 orthoses) is the best and should be chosen: for this child there should be 2 orthoses prescribed. In the rest of the cases the study did not give the clear answer what is the best decision for these children. We can guess that because the patient No. 2 was very young (3 years old), his gait pattern was very immature and easy to be influenced by outer factors.

When a single parameter such as stance (non-affected side) is considered as sign of improvement, such amelioration is observed in 3 patients while walking with 2 orthoses and in 2 of them there is the improvement of gait velocity. Also, such important parameter for the possible development of scoliosis as pelvis position in frontal plane depends on the number of orthoses worn by children, but the answer which number is better should be considered individually.

An additional factor which can influence the obtained results was the trunk movements, which were not monitored in the present study. In CP patients the trunk can move with various patterns, depending on the type of functional dysfunction and compensatory mechanisms, influencing the overall gait pattern [12], [25].

In the available literature there is no study which tried to compare the influence of use one or two orthoses on the gait of children with unilateral spastic cerebral palsy. Therefore, it is difficult to discuss the results of the present preliminary study with data published in the literature. In some centers, the hemiplegic CP patients receive two orthoses [2], [10], in some only one, for the palsied limb [9], [22], but no reason or explanation for either approach is given.

5. Conclusions

The shortcoming of the present study is a low number of the patients in the observation. To our knowledge, this is the first study which analyzed the influence of number of orthoses on the gait in hemiplegic CP children. Therefore, further studies are needed to develop a clear protocol which can help to make a decision about the number of orthoses. From these preliminary results, it is clear that patients' reaction to number of orthoses is individual. So, these results suggest that when the orthotic devices are foreseen for patients with hemiplegic cerebral palsy, the objective, instrumented gait analysis can be used to take the best decision whether one or two orthoses should be prescribed. Further studies may probably lead to the finding of some predictors based on the barefoot walking.

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