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Research of the spatial-temporal gait parameters and pressure characteristic in spastic diplegia children

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Purpose: Spastic diplegia is the most common form of cerebral palsy. It presents with symmetric involvement of the lower limbs and upper limbs. Children with spastic diplegia frequently experience problems with motor control, spasticity, and balance which lead to gait abnormalities. The aim of this study is twofold. Firstly, to determine the differences in spatial-temporal gait parameters and magnitude of plantar pressure distribution between children with spastic diplegia (CP) and typical children. Secondly, to compare and evaluate main changes of plantar pressure and spatial-temporal gait parameters instead of data between spastic diplegia children with prescribed ankle – solid foot orthosis (AFOs) and without using AFOs. *Methods*: The evaluation was carried out on 20 spastic diplegia children and 10 age-matched children as a control group aged 6–15 years. Twenty children with spastic diplegia CP were divided into two groups: ten subjects with prescribed AFOs and ten subjects without use of assistive device. Patients used the AFOs orthosis for one year. Measurements included in-shoe plantar pressure distribution and spatial-temporal gait parameters. *Results*: Spatial-temporal gait parameters showed meaningful difference between study groups in velocity, stride length, step length and cadence ($p < 0.05$). However no significant differences between patients with and without AFOs were found ($p > 0.05$). Significant differences between typical and spastic diplegia children with AFOs were observed in the magnitude of plantar pressure under the toes, the metatarsal heads, the medial arch, and the heel ($p < 0.05$). For typical subjects, the highest pressure amplitudes were found under the heel and the metatarsal heads, while the lowest pressure distribution was under the medial arch. In CP patients the lateral arch was strongly unloaded. The peak pressure under heel was shifted inside. *Conclusions*: Collected data and calculated scores present a state of the gait in test groups, showed the difference and could be valuable for physicians in decision making by choosing qualitative therapy. Furthermore, it allows predicting probability of further possible changes in gait of spastic diplegia patients with AFOs and without it. In conclusion, our current results showed that the use of AFOs, prescribed on a clinical basis by doctors improves gait patterns and gait stability in children with spastic cerebral palsy.

Key words: *spastic diplegia, spatial-temporal parameters, gait, pressure distribution, ankle-foot orthosis*

1. Introduction

Human gait is the most common of all human movements. It is one of the more difficult movement tasks and only when this complex neuromuscular system is distributed by neurological damage, gradual degenerations, injury or fatigue it is possible to imagine this complex biomechanical system and its motor processes. Many papers published on human gait, the measurement techniques vary considerably. Each of the results appears to be characteristic of the understanding and interests of the investigator. Neurological disorders tend to look at appropriate measured parameters such as stride length, cadence, and velocity. For example, disorders like multiply sclerosis could be evaluated by gait tests also and gait patterns show the level/grade of disease and are helpful for

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clinical decision making [23]. The term cerebral palsy (CP) refers to any one of a number of neurological disorders of the development of movement and posture, causing activity limitations that appear in infancy or early childhood and permanently [1], [14]. The motor disorders of CP are often accompanied by disturbance of sensation, cognition, communication, perception and/or behavior and/or by other disorders. Spastic diplegia is the most common form of cerebral palsy. It presents with symmetric involvement of the lower limbs and upper limbs. Children with spastic diplegia frequently experience problems with motor control, spasticity, and balance that lead to gait abnormalities [15], [16]. Evaluating the lower limbs dysfunction in children with CP is a complex process. Some authors state that children with CP are characterized by kinematical (walking velocity, stride length, single and double support, step width) and kinetic parameters (power, forces and moments) in assessment gait parameters [8], [12], [16]. However, abnormal gait patterns in spastic diplegia associated following symptoms: increased muscle tone, or a velocity dependent resistance to passive muscle stretch, in synergistic muscle groups, a loss of selective muscle control, deficient equilibrium reactions, and relative imbalance of muscle forces across the joints in the lower extremities [13], [20], [22]. Crouch gait is a common pathological walking pattern adopted by individuals with cerebral palsy that is characterized by excessive hip and knee flexion [20]. CP requires a multifaceted approach to rehabilitation. Most important factors should be identified and therefore general purposes on following topic are to determine the differences in spatial-temporal gait parameters between children with spastic diplegic CP and typical children in order to develop more effective strategies for producing positive functional outcomes [1], [4], [8], [15], [17]. Prognostic tools and variety of statistical, musculoskeletal models are used for evaluation of main kinematical and kinetic parameters and their correlations with other factors coursing to the motor functional disorders [1], [3], [19]. Physicians usually prescribe AFOs with a recommendation how to prevent the development or progression of foot deformity and to improve the dynamic efficiency of the spatial diplegic child's gait [24]. The proposed effects associated with AFOs include assistance in foot clearance at swing, correction of foot prepositioning at initial contact, stability in stance phase and reduction of energy expenditure [21], [24]. Previous scientific results declare the efficiency of using AFOs as a therapy which improves spatial-temporal gait parameters and gait stability in children with spastic CP [12]. There are different types of braces from rigid and articulated types and they are produced by different manufacturers according to function and not definition, since they were prescribed by physicians. Patients who have a tendency to crouch could benefit from a solid type AFO that induces knee extension or a ground reaction type AFO that prevents excessive forward movement of the tibia and keeps the ground reaction force anterior to the knee. Regularity of using AFOs also courses gait patterns and influences testing parameters [12]. The aim of this study has two tasks. Firstly, to determine the differences in spatial-temporal gait parameters and magnitude of plantar pressure distribution between children with spastic diplegia (CP) and typical children. Secondly, the comparison and the evaluation of main changes of plantar pressure parameters and spatial-temporal data between spastic diplegia children with prescribed ankle–solid foot orthosis (AFOs) and without using AFOs were presented.

2. Materials and methods

2.1. Subjects

The evaluation was carried out on 20 spastic diplegia children (45% boys) and 10 typical (normal development ND) children (50% boys) as a control group (Table 1). All subjects were aged 6–15 years. Spastic diplegia patients instead of subjects were all able to walk without support and were therefore classified as Gross Motor Function Classification (GMFC) System level I or II [3], [18]. The typical children were not assessed with the GMFC. The following inclusion-exclusion criteria were used for selection of children with CP: children with CP had to have a clinical diagnosis of spastic diplegic CP, showed plano-valgus on standing or walking or both, children with CP had to be able to walk without use of assistive devices, and children with CP had to have not undergone orthopedic surgery within at least one year and six months after botulinum toxin type A injections prior to the experiment. Patients were excluded if they had received botulinum injections within 6 months or had undergone orthopedic surgery within one year prior to the evaluation. Twenty children with spastic diplegia CP were divided into two groups: ten patients instead of subjects with prescribed solid AFOs and ten patients instead of subjects not using assistive device. Patients used the

AFOs orthosis for one year. All subjects received full information about the study before giving signed consent. The local ethics committee approved the study. To provide baseline data for comparison with patients' results, 10 age-matched typical subjects were also assessed using the study protocol. Subject's body weight was measured using a scale with resolution of 100 g. The subject's height was measured by stadiometer.

2.2. Measurement protocol

The foot shape was identified for all subjects systematically set in balanced bipedal position on a direct sight (Fig. 1).

Fig. 1. The identification of foot shape

CP children's prescribed ankle-foot orthosis were removed during the experiment. Prior to data collection, all participants had an opportunity to practice walking. The participants walked at a comfortable gait speed in three trials. For measuring spatial-temporal gait parameters an optoelectronic system with eight cameras (Motion Analysis System, USA) and two AMTI (Advanced Mechanical Technology, Inc., USA) platforms were used. The spatial-temporal gait parameters included walking velocity, stride length, step length, cadence, and percentages of single- and total-limb support. For measurement of plantar pressure distribution, subjects were instructed to walk a distance of approximately 10 meters at their habitual speed inside a gait laboratory. The data during walking were measured with a pedobarograph (T & T medilogic Medizintechnik, GmbH Munich, Germany) based on shoe insoles with capacitive sensors (max. 240 SSR sensors per insole, depending on size and shape) [19]. The sample frequency was 60 Hz. Trial replications were done three times for left and right foot separately. To quantify plantar pressure distribution, the maximum magnitude of plantar pressure (peak pressure) under seven anatomical masks such as: toes (mask 1), 2nd–5th metatarsal heads (mask 2), 1st metatarsal head (mask 3), lateral arch (mask 4), medial arch (mask 5); lateral heel (mask 6); and medial heel (mask 7) were measured using a commercially available toolbox (Fig. 2).

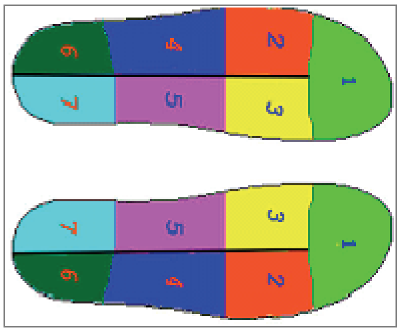

Fig. 2. The definition of different masks used in this study: Mask 1 = toes; Mask 2 = 2nd–5th metatarsal heads;| Mask 3 = 1st metatarsal head; Mask 4 = lateral arch; Mask 5 = medial arch; Mask 6 = lateral heel; and Mask 7 = medial heel

The pressure distribution of each anatomical area was calculated for each mask. Maximum pressure was defined as the greatest pressure in each anatomical area of foot in a single step, and these values were averaged separately for each mask over 10 steps.

2.3. Statistical analysis

The dataset included gait cycles from 20 spastic diplegia patients and 10 healthy subjects. Means and standard deviations were calculated for the total subject sample for the data from the gait analysis. For gait variables, an ANOVA for repeated measurements was applied to evaluate differences in quantitative walking parameters. Comparisons between groups (patients versus controls) were performed using one way ANOVA and Scheffe Post-Hoc and intra-subject comparison (i.e., right and left side) was performed using repeated ANOVA. A value of $p < 0.05$ was considered significant.

3. Results

3.1. Subjects demography

The baseline demographic characteristics of the subjects enrolled in the study were as follows. Each

Table 1. Subject demographic characteristics

Group	Control	Spastic diplegia CP with AFOs	Spastic diplegia CP without AFOs	Comparison of control vs. spastic diplegia CP with AFOs		Comparison of control vs. spastic diplegia CP without AFOs	
Number	10	10	10	Difference	*p*-value	Difference	*p*-value
Age, years Mean (SD)	11.8 (3.5)	9.2 (4.4)	11.0 (2.8)	2.6	$p = 0.320$	0.8	$p = 0.757$
BMI, kg/m^2 Mean (SD)	19.4 (3.9)	16.1 (7.2)	18.1 (2.8)	3.3	$p = 0.620$	1.3	$p = 0.567$
Height, cm Mean (SD)	142.1 (12.3)	131.1 (22.1)	141.8 (15.7)	11.0	$p = 0.170$	0.3	$p = 0.987$

group consisted of 10 subjects. The mean age of the children with CP with prescribed AFOs and without use of AFOs were 9.2 (4.4) years and 11.0 (2.8) years, respectively. The mean height was 131.1 (22.1) cm and 141.8 (15.7) cm for children with CP with prescribed AFOs and without use of AFOs, respectively. Additionally, for children with CP with prescribed AFOs and without use of AFOs the mean BMI was 16.1 (7.2) kg/m^2 and 18.1 (2.8) kg/m^2, respectively. Those of the typical children were 11.8 (3.5) years, 142.1 (12.3) cm, and 19.4 (3.9) kg/m^2, respectively. Five of the children with CP were classified as GMFC level I, fifteen children were classified as GMFC level II. Data (mean ± SD) for the subjects demography of both the children with CP (with AFOs and without AFOs separately) and the typical children are shown in Table 1. No significant difference was observed between spastic diplegia CP and control group for age, body mass, height, and gender ratio ($p > 0.05$).

3.2. Assessing spatial-temporal gait parameters

Data for the spatial-temporal gait parameters of both the children with CP using AFOs and the children with CP without AFOs were compared to typical children (Table 2).

The analysis shows that significant differences between typical and spastic diplegia children were observed in the velocity, stride length, step length and cadence ($p < 0.05$). For CP children with prescribed AFOs and without use of AFOs the mean velocity was lower an average of 2.7% and 17.9%, respectively compared with the control group (1.12 m/sec in typical subjects versus 1.09 m/sec in spastic diplegia using AFOs and 0.92 m/sec in spastic diplegia without AFOs, $p < 0.05$), Fig. 3a. On the same note the stride length was reduced an average of 13.2% and 16.2% for CP children with prescribed

Table 2. Spatial-temporal gait parameters for typical subjects and spastic diplegia patients

Gait parameters	Groups			Comparison of typical vs. CP with AFOs		Comparison of typical vs. CP without AFOs	
	Typical	Spastic diplegia with AFOs	Spastic diplegia without AFOs	Difference	*p*-value	Difference	*p*-value
Velocity (m/sec) Mean (SD)	1.12 (0.13)	1.09 (0.16)	0.92 (0.24)	0.03	$p < 0.05$	0.2	$p < 0.05$
Stride length (cm) Mean (SD)	102.4 (9.5)	88.9 (13.6)	85.8 (21.4)	13.5	$p = 0.02$	16.6	$p = 0.04$
Step length (cm) Mean (SD)	51.03 (4.9)	43.4 (8.5)	44.2 (11.4)	7.63	$p = 0.02$	6.83	$p = 0.04$
Cadence (steps/min) Mean (SD)	125.2 (17.6)	148.0 (21.6)	131.7 (21.3)	–22.8	$p = 0.02$	–6.5	$p = 0.49$
Single support time (%) Mean (SD)	35.8 (2.7)	35.1 (5.6)	33.2 (7.6)	0.7	$p = 0.6$	2.6	$p = 0.3$
Total support time (%) Mean (SD)	60.4 (5.1)	60.8 (3.5)	58.8 (3.9)	–0.4	$p = 0.8$	1.6	$p = 0.45$

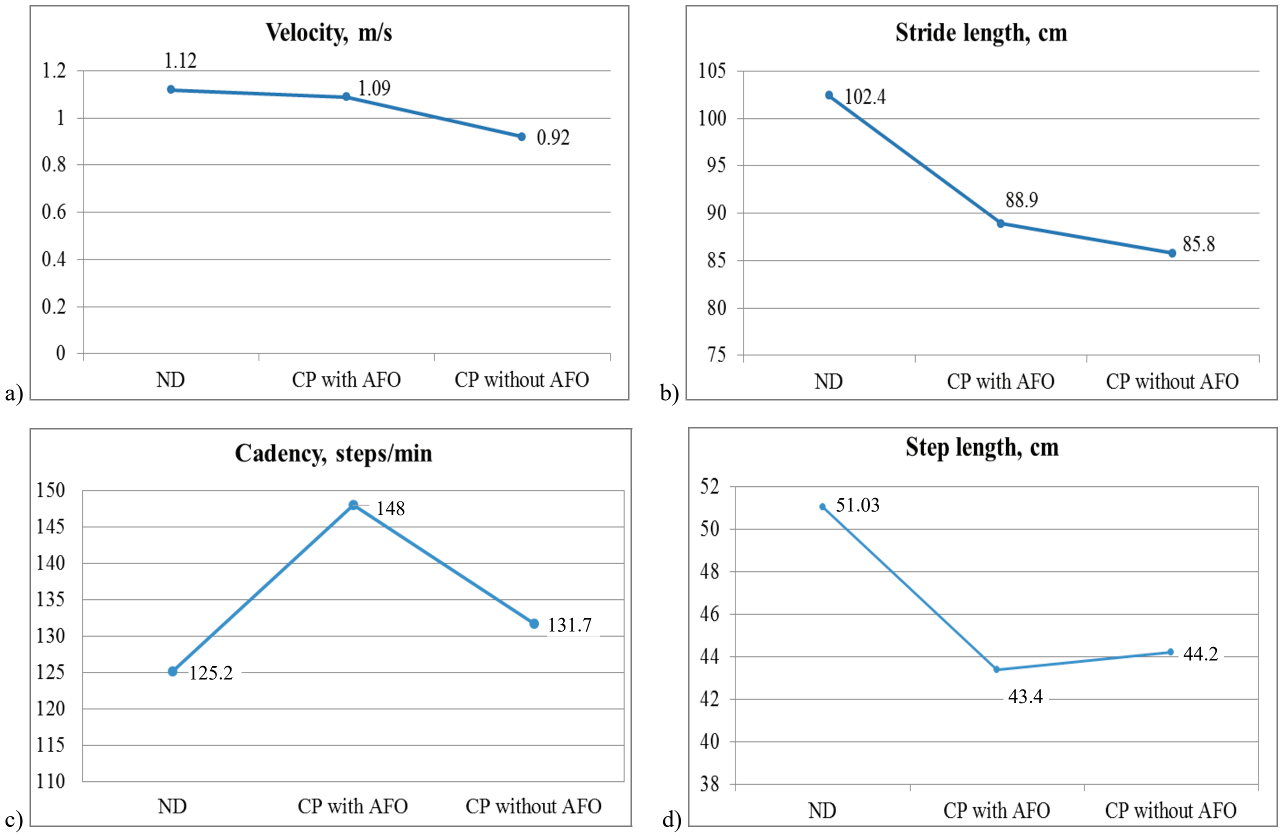

Fig. 3. Spatial-temporal gait variations in subject groups tested

AFOs and without use of AFOs, respectively (102.4 cm in typical subjects versus 88.9 cm in spastic diplegia using AFOs and 85.8 cm in spastic diplegia without AFOs, $p < 0.05$), Fig. 3b. In addition, results suggest a 15% and 13.4% reduction in mean step length in CP patients with prescribed AFOs and without use of AFOs, respectively versus those in the control group (51.03 cm in typical subjects versus 43.4 cm in spastic diplegia with AFOs and 44.2 cm in spastic diplegia patients without AFOs, $p < 0.05$), Fig. 3d. However, the cadence was on average 18.2% higher in spastic diplegia patients using AFOs (148.0 steps/min in spastic diplegia patients versus 125.2 steps/min in typical subjects, $p < 0.05$), Fig. 3c. No between-group statistically significant differences were observed for the single support time (%) and total support time (%). The analysis shows also no statistically significant differences between CP patients with and without AFOs in spatial-temporal gait parameters, $p > 0.05$.

As is seen in Fig. 3, the spatial-temporal gait parameters – velocity, stride length, and step length in spastic diplegia group displayed lower values of these parameters. However, the cadence is higher in CP children. Between spastic diplegia patients instead of subjects with prescribed AFOs and without AFOs they also differ. Thus in spastic diplegia subjects using AFOs demonstrated an increase in walking velocity and their stride length was wider than of those not using it. That proves that AFOs improves gait parameters for spastic diplegia patients, but still it does not make the walk easier and more treatment and therapy are required.

3.3. Assessing plantar loading during walking with habitual speed

Each participant was asked to wear pedobarographic pressure insoles in their shoes for 10 min to allow insole acclimatization and potentially enhance the reliability of the measurement. No between-foot difference was observed for any of the measured variables ($p > 0.05$). Thus, further assessment was performed on the dominant side. Table 3 summarizes the mean (SD) magnitude of plantar pressure distribution extracted from pedobarograph insoles during walking for typical group and spastic diplegia patients.

The analysis shows that significant differences between typical and spastic diplegia children with AFOs were observed in the magnitude of pressure distribution under the toes (mask 1), the metatarsal heads (masks 2, 3), the medial arch (mask 5), and the heel (masks 6, 7), ($p < 0.05$). The magnitude of pressure distribution under the toes was an average of 74.3% and 80% higher in CP group with prescribed AFOs and without use of AFOs, respectively versus those in the control group (3.5 N/cm^2 in typical subjects versus 6.1 N/cm^2 in spastic diplegia using AFOs and 6.3 N/cm^2 in spastic diplegia without AFOs). Additionally, the magnitude of pressure distribution under the metatarsal heads was by an average of 67.8% and 74.6% higher in CP patients with prescribed AFOs and without use of AFOs, respectively (5.9 N/cm^2 in typical subjects versus 9.9 N/cm^2 in spastic diplegia using AFOs and 10.3 N/cm^2 in spastic diplegia without AFOs, $p < 0.05$). Under the medial arch (mask 5) the magnitude of pressure distribution was on average 65% higher in CP with AFOs and 90% higher in CP without AFOs compared with the typical group (2.0 N/cm^2 in typical subjects versus 3.3 N/cm^2 in spastic diplegia using AFOs and 3.8 N/cm^2 in spastic diplegia without AFOs, $p < 0.05$). However, the mean (SD) magnitude of pressure distribution under the heel (masks 6, 7) was significantly reduced by an average of 30.1% and 31.3% in CP group with prescribed AFOs and without use of AFOs, respectively compared with the typical (8.3 N/cm^2 in typical subjects versus 5.8 N/cm^2 in spastic diplegia using AFOs and 5.7 N/cm^2 in spastic diplegia without AFOs, $p < 0.05$). The analysis shows that between CP patients with and without AFOs statistically significant differences were not observed for the magnitude of pressure distribution ($p < 0.05$). For ND subjects, the highest pressure amplitudes were found under the heel and the metatarsal heads, while the lowest pressure distribution was under the medial arch. For CP

Table 3. Plantar pressure comparison between CP patients and typical subjects

Masks	Typical	CP with AFOs	CP without AFOs	Comparison of typical vs. CP with AFOs		Comparison of typical vs. CP without AFOs	
				Difference	*p*-value	Difference	*p*-value
Toes (mask 1) P [N/cm^2] Mean (SD)	3.5 (0.8)	6.1 (1.2)	6.3 (1.8)	–2.6	$p < 0.05$	–2.8	$p < 0.05$
Metatarsal heads (masks 2, 3) P [N/cm^2] Mean (SD)	5.9 (1.3)	9.9 (2.4)	10.3 (3.1)	–4.0	$p < 0.05$	–4.4	$p < 0.05$
Lateral arch (4) P [N/cm^2] Mean (SD)	3.6 (0.6)	1.6 (0.7)	1.7 (0.6)	2.0	$p > 0.05$	1.9	$p > 0.05$
Medial arch (mask 5) P [N/cm^2] Mean (SD)	2.0 (0.6)	3.3 (1.0)	3.8 (1.2)	–1.3	$p < 0.05$	–1.8	$p < 0.05$
Heel (masks 6, 7) P [N/cm^2] Mean (SD)	8.3 (0.6)	5.8 (0.7)	5.7 (0.9)	2.5	$p < 0.05$	2.6	$p < 0.05$

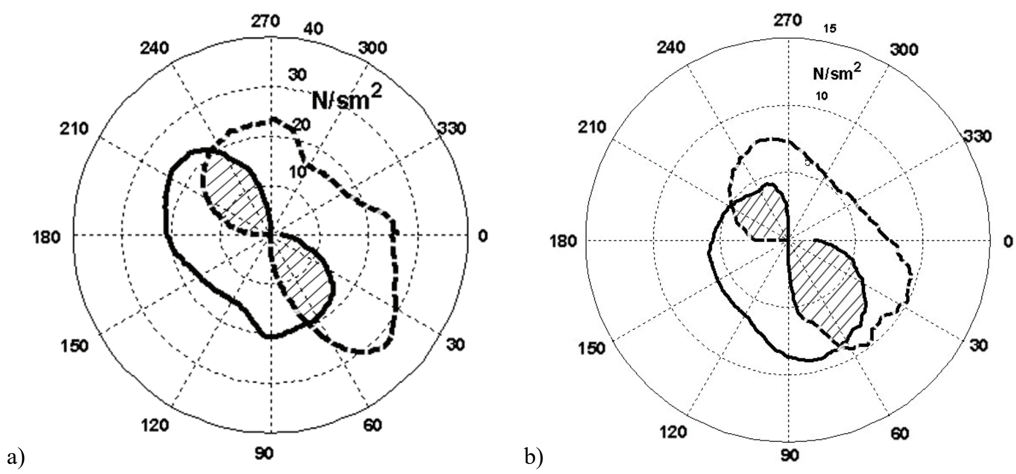

Fig. 4. Phase diagram of plantar pressure during one step: (a) typical child, (b) CP child

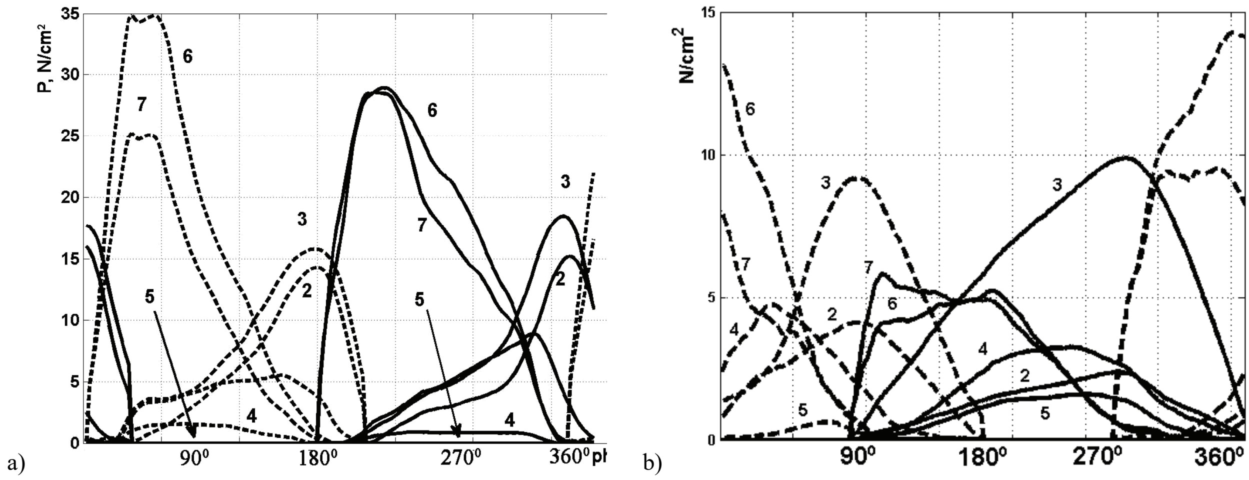

Fig. 5. Phase diagram of pressure value in all masks during one step: (a) typical child, (b) CP child

patients the lateral arch was strongly unloaded, the peak pressure under the heel was shifted inside, and the toes of both feet were strongly involved in propulsion. In Figs. 4, 5, examples of phase diagrams of plantar pressure during one step for typical and CP children have been presented: the solid curve is a left foot, and the dashed curve is a right foot. The double support phase is defined by the intersections of the two areas marked by solid and dashed curves. For the typical subjects it is symmetric and with equal-area (Fig. 4a). However, for CP patients the phase is neither symmetric nor with equal-area (Fig. 4b).

For the analysis of a gait, the phase diagram of pressure distribution in each mask during step cycle has been presented in Fig. 5. Considerable excess of pressure under 1st metatarsal head (mask 3) was observed. It was found that CP patients at the end of the midstance phase have a tendency to fall. The motoneurological response of the CP patients and uncertainty of walking is caused by the raised pressure under the forefoot. Beside the ascertained differences in the magnitude of pressure for typical and CP children, attention should be paid to function's curves. The pressure under the front part of foot for typical children (masks 2 and 3) increases slowly, then sharply decreases. However the pressure function line under the forefoot for CP children (masks 2 and 3) is symmetric.

4. Discussion

The desired outcome of this research was to explain differences in spatial-temporal gait parameters between children with spastic diplegic CP, who had GMFC system levels of I or II, and typical children, and to identify and set the quantity of the differences. Children with spastic diplegic CP were divided into two groups: one using AFOs and another without AFOs and their tests results were compared as well. Our results did not show any significant difference between spastic diplegic CP and control group for age, body mass, height, and gender ratio ($p > 0.05$). However significant differences between typical and spastic diplegia children were observed in the velocity, stride length, step length, and cadence ($p < 0.05$). Our findings proved results of previous studies reporting significantly different gait parameters in children with spastic diplegic CP than in typical children, especially of lower spatial-temporal gait parameters such as velocity, stride length, and step length [6], [8]. The velocity was higher in typical subjects compared with spastic diplegia patients. On the same note the stride length and the step length in typical subjects was longer compared with CP group. However, the cadence was higher in spastic diplegia patients using AFOs. There were no significant differences ($p > 0.05$) in the single support time and total support time between the three groups. Because of motor weakness and poor voluntary motor control, children with CP use a wider step width than typical children [1], suggesting that children with CP may choose a wider base of support in order to stabilize the center of mass. Furthermore, step width showed correlation with walking velocity, cadence, and stride length. Thus, children with a wider step width tend to have greater difficulty in gait performance [22]. As expected, our study showed difference in spatial-temporal gait parameters such as velocity, stride length, step length, and cadence in patients with prescribed AFOs. Spastic AFOs demonstrated an increase in walking velocity and their stride length was wider than in subjects not using them. In contrast to the findings by White et al. [24] and Dursun et al. [10] which reported that the use of AFOs significantly increased walking velocity and stride length, but did not change in cadence, our research results showed that the cadence mostly depends on the other spatial-temporal gait parameter – velocity and it is higher in CP children. Between spastic diplegia patients with prescribed AFOs and without AFOs they also differ. Spastic diplegia children with AFOs attain higher velocities especially by increasing both their cadence and their stride length. There is a theory in sport, especially for runners during sprint, that the highest speed might be achieved in higher cadence. They are trained to make more steps and more support the ground. The higher cadence actually takes less effort, improves forward momentum, decreases injuries, and increases speed. We think the same we found in our study results, patients with prescribed AFOs showed better spatial-temporal gait parameters because of longer support time during work and longer stride. Effects of growth and age influence children with CP gait and it is known that without any procedure or treatment their gait patterns decline. Using AFO diminishes this progression as well as improves gait parameters and provides a stable base of support, which helps in improving the efficiency of gait training. Overwise, Buckon et al. [5] found that the use of AFOs in CP children increased stride length, reduced cadence but did not significantly diminish walking velocity. Some authors reported that AFOs reduced exertion during standing [7] and walking, while others [5] demonstrated that it had no effect on exertion and did not change oxygen consumption at comfortable velocity. The authors observed that the increase in velocity that had been demonstrated in long-distance walking, however, does indicate a reduction in energy costs.

Our results show higher pressure distribution under the toes, metatarsal heads, and medial arch for CP patients compared with typical ones ($p < 0.05$). However the mean magnitude of plantar pressure under the heel was significantly reduced in the CP group ($p < 0.05$). It is in agreement with [11], where in diplegic children average plantar pressure was significantly increased in the forefoot and midfoot and decreased in the rearfoot. The statistically significant differences were not observed for the magnitude of pressure distribution between CP patients with and without AFOs ($p > 0.05$). Chang et al. [9] measured nine children with mild cerebral palsy who performed the short distance stride repetitions while wearing and removing the customized external strap orthosis. A significant difference in mean peak plantar pressure of the first metatarsal, medial heel, and lateral heel was observed between wearing and removing the orthosis ($p < 0.05$). However in our study CP children wore the ankle-foot orthosis for one year and it was removed during the experiment. The present findings need to be interpreted in the context of several limitations. First, we assessed plantar pressure using the participant's own shoes. However all of the participants were tested while wearing acceptable athletic shoes. Another limitation is the potentially small sample size for a valid between-group comparison.

5. Conclusions

It should be noted that no significant difference was observed between spastic diplegia CP individuals (with prescribed AFOs and without using it) and control group for age, body mass, height and gender ratio ($p > 0.05$). Spatial-temporal gait parameters showed meaningful difference between study groups in velocity, stride length, step length and cadence ($p < 0.05$). Meaningful rates were presented and they proved the results of previous studies. Plantar pressure distribution data showed feet support characteristics during step, main scores and areas presented for spastic diplegia CP subjects and typical group. Collected data and calculated scores presented a state of the gait in test groups, showed the difference and could be valuable for physicians in decision making by choosing qualitative therapy. Furthermore, one can predict the probability of further possible changes in gait of spastic diplegia patients with AFOs and without it. In conclusion, our current results showed that the use of AFOs, prescribed on a clinical basis by doctors improves gait patterns and gait stability in children with spastic cerebral palsy.

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