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EVALUATION OF KNEE JOINT STIFFNESS IN CHILDREN WITH CEREBRAL PALSY

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Abstract: *The knee joint stiffness is a very complex issue, which occurs in many children with cerebral palsy (CP). Therefore, in children with CP are carried out studies both clinical and biomechanical. They are carried out to evaluate the locomotors system and to choose the most appropriate treatment. Biomechanical evaluation of the musculoskeletal system focused on the analysis of gait. The aim of the research presented in this paper was to evaluate of the knee joint stiffness in children with CP based on the designated during gait studies of kinematic magnitudes.*

Keywords: Knee joint, Stiffness, Stiff-knee gait, Cerebral palsy (CP), Range of motion (ROM).

1. Introduction

For many years, children with impaired muscle tone were subject to many clinical studies. In recent years, into these studies were included biomechanical test. Selection of the best method of treatment for a given patient depends on a correct diagnosis of his health. In order to select an appropriate method of treatment it should be known precisely the mechanisms of muscle tone regulation, as well as diseases causing the occurrence impairment of muscle tone (Olchowik, 2009). Stiffness beside spasticity and dystonia is one of the form of increased muscle tone. Analysis of the knee joint stiffness is very important in studies of gait of children with impaired muscle tone, especially for children with CP. The knee joint stiffness is an impairment of muscle tone, and in particular malfunction of rectus femoris. This appear especially during gait, e.g. during initial swing of the rectus femoris what limits the rate of knee flexion. Rectus femoris transfer surgery is often performed to treat stiff-knee gait (Gage, 1993 and Reinbolt, 2008). The knee joint stiffness influences on all phases of child's gait, and first of all, makes it difficult to bend and unbend. The knee joint stiffness causes excessive flexion, limited extension and a smaller range of motion of the knee joint (Goldberg, 2003 and Van der Krogt, 2010 and Thawrani, 2012). During flexing or extension stiff of lower limb it appears continuous resistance. Sometimes while moving the lower limb may occur jumping symptom of reduction of muscle tone, so-called "cogwheel rigidity". It is a characteristic symptom of tension and relaxation of antagonist muscles that occurs in people with intensified muscle tone that primarily can be observed when straightening the knee. Since patients with stiff-knee gait have limited knee flexion ability, they might use for example pelvic hike during swing phase of gait to assist their toe clearance (Böhm, 2014 and Campenhouta, 2014). These plantigrade gait determinants, such as knee flexion during stance phase, pelvic movements, and joint coordination, cause displacement of the body's centre of mass in the direction shifted in the side axis of the limb (Massaad, 2004).

For doctors involved in the treatment of disorders of muscle tone in patients with CP the selection of the most appropriate method of treatment is a major challenge. In recent years, a biomechanical methods, in particular gait analysis, make it easier to evaluate of the musculoskeletal system. Analysis of gait parameters obtained during the study delivers various information concerning a given pathology. Commonly during the studies are evaluated: spatio-temporal parameters, kinematic and kinetic quantities and ground reaction forces. The kinematic parameters usually are read ranges of movements in individual joints. In clinical practice it is rare to evaluate the stiffness of knee joint basing on only one measured kinematic parameter such as the knee angle in the sagittal plane.

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2. Materials and methods

Twelve patients with bilateral cerebral palsy, (8 boys and 4 girls) with mean age 10.6 (SD = 3.7) years with mean weight 32 (SD = 15.1) kg and with mean height 136 (SD = 22.6) cm were compared to fifteen typical developing children (TP) (7 boys and 8 girls) with mean age 10 (SD = 2.8) years, with mean weight 34 (SD = 13.4) kg and with mean height 138 (SD = 18.2) cm (these data were taken from the publications Goldberg et al., 2006). All children's parents signed an informed consent form.

Studies have been conducted in John Paul II Upper Silesian Child Health Centre. The subject of this study was analysis of gait in children with cerebral palsy. Anthropometric data of individual children with CP are given in Tab. 1.

Tab. 1: Anthropometric data of individual children with CP.

patient	sex	age [years]	weight [kg]	height [cm]
No 1	boy	13	40	153
No 2	girl	6	16	110
No 3	boy	7	19	113
No 4	boy	7	16	110
No 5	boy	15	45	150
No 6	boy	12	30	146
No 7	boy	12	50	150
No 8	girl	6	23	120
No 9	boy	15	60	170
No 10	girl	6	15.5	113
No 11	girl	13	25	135
No 12	boy	15	42	168

The study of gait analysis was conducted in order to evaluate the stiffness of knee joint. System for three dimensional motion analysis BTS Smart was used. This system contained eight optoelectronic camera operating in the infrared range. The registered measurements allowed the determination of the kinematic parameters based on the modified Davis' model. The following parameters were read from the obtained plots:

- parameter T [% gait cycle] – time at which followed detachment toes from the ground (toe-off),
- parameter 1 [°] – peak knee flexion angle,
- parameter 2 [°] – range (ROM) of knee flexion in early swing measured from toe-off to peak flexion,
- parameter 3 [°] – total range of knee motion (knee ROM total),
- parameter 4 [% gait cycle] – timing of peak knee flexion in swing.

The standard diagram dependence the angle of the knee joint in the sagittal plane on the phase of gait, along with the selected parameters, is shown in Fig. 1. Stiffness in the knee joint occurs when three or more of the parameters deviate from normal values. The stiffness of the knee occurs when at least two parameters shown in Fig. 1 are abnormal. However, when the two parameters are abnormal it cannot be concluded clearly whether stiffness of the knee joint occurs or not. Parameters from 1 to 3 are considered abnormal when their value are at least twice smaller than the standard deviation value of the parameter 4 considered normative. However, if the parameter value is at least equal to twice the standard deviation of the normative value is considered to be abnormal (Goldberg et al., 2006).

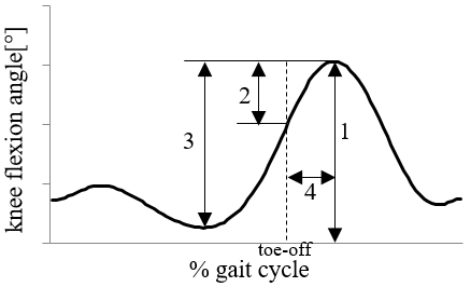

Fig. 1: The knee angle in the sagittal plane with marked parameters.

3. Results

In the case of people with cerebral palsy should be also checked if they have a gait excessively bent knees (a condition called crouch gait). In such case these persons may have stiffness in the knee during the whole gait cycle, and the value of angle of flexion of the knee joint considerably differs from normal

values. This phenomenon also affects the value of the parameter 1, i.e. peak knee flexion angle. For people with crouch gait should be taken into account the value of angle of flexion of the knee joint during initial contact. Fig. 2 shows a graph of the abnormal knee angle of the phase gait cycle for one of the patients with respect to healthy children. All results of study were summarized in Tab. 2 and referred to the standard literature after analyzing the research group in the author's program (Goldberg S. et al., 2006).

Tab. 2: Measures of stiff-knee gait (where L-left lower limb, R-right lower limb).

	Parameter T [%]		Parameter 1 [°]		Parameter 2 [°]		Parameter 3 [°]		Parameter 4 [%]		Stiff -knee
Lower limb	L	R	L	R	L	R	L	R	L	R	
T P	62 ± 1		66 ± 5.3		31 ± 4.3		60 ± 6.8		13 ± 1.2		
Patient 1	61.0	58.0	49.8	67.1	17.1	11.6	34.7	38.9	14.0	10.5	L
Patient 2	55.0	66.0	53.0	49.0	20.8	23.6	28.8	24.5	20.0	24.0	L, R
Patient 3	60.0	54.0	70.1	78.6	24.6	12.6	42.5	60.1	21.0	15.0	
Patient 4	65.0	64.0	59.4	62.8	23.4	11.9	57.4	55.8	19.0	21.0	
Patient 5	80.0	74.0	53.6	61.3	6.4	5.4	9.9	8.4	21.0	15.0	L
Patient 6	66.0	84.0	33.8	54.6	1.3	5.2	7.4	10.0	23.0	16.0	L, R
Patient 7	77.0	74.0	72.1	75.8	7.6	9.4	10.6	8.3	18.0	26.0	L, R
Patient 8	64.0	65.0	70.8	76.4	14.5	13.4	20.6	17.6	20.0	15.5	L, R
Patient 9	61.0	69.0	72.9	63.8	24.1	25.9	61.4	70.7	23.0	17.0	
Patient 10	78.0	81.0	77.2	76.5	11.9	16.3	37.0	38.6	9.0	9.0	
Patient 11	81.0	76.0	66.7	63.5	9.8	9.2	20.3	14.5	12.0	15.0	
Patient 12	76.0	71.0	100.8	97.5	1.9	2.6	8.8	10.2	7.0	9.0	

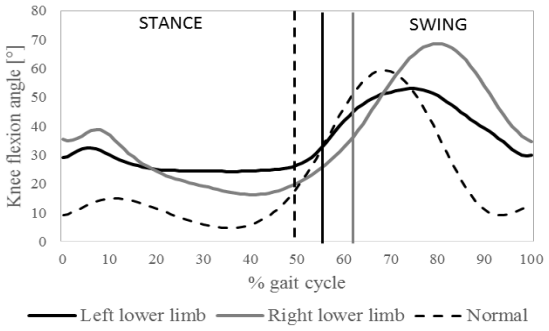

Fig. 2: The knee angle in the sagittal plane (left and right lower limb) for one of the children with CP in relation to control group (TP).

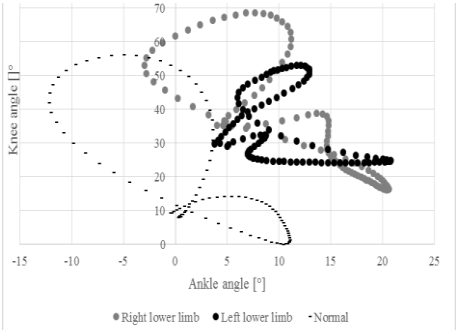

Fig. 3: Intra – limb coordination of knee and ankle for gait cycles for one child with CP in relation to control group (TP).

Fig. 3. describes differences in joints coordination (knee and ankle) for children with CP and healthy ones. Pattern of coordination of knee-joint and ankle for child with stiffness in left knee joint is deeply

impaired both for left and right side. Healthy children has initial contact coordinates at (-1; 10), but for CP-children values are deeply different - (4; 35.4) for right and (5; 29) for left limb. When picking up fingers from base/ground coordinates for healthy children are (-12; 40), and for CP-children respectively for right limb (-1; 45.7), and left (10.2; 32.2).

4. Conclusions

The results of the study gait, that were presented in Tab. 2, allow us to conclude that among twelve investigated children, two children has a stiff-knee joint of left lower limb and four children has a stiff-knee joint of both lower limbs. Only one patient acknowledged a lack of stiffness of knee joints of both lower limbs. However, for a few patients it cannot be clearly determined presence of stiffness of knee joint of any of the lower limbs. One patient had abnormal values for all four parameters for both lower limbs. Analysis of results for majority of patients shows that most deviations from normal values are related to the parameter 2 and 3. On the other hand first parameter is incorrect in comparison to the standard value for the four patients. For two of patients its value is invalid for the both lower limbs and for other two patients only for one lower limb. In this article been made to evaluation of intra-limb coordination of angles of knee and ankle during gait because of the fact that the stiffness of the knee changes the pattern of motion in all joints of the lower limb.

One of the universal conclusions from the study is the necessity to join a routinely generated research reports with gait analysis evaluation stiffness of the knee joint in children with impaired muscle tone with cerebral palsy.

Patients with crouch gait may suffer or not stiffness in the knee joint. Numeric data of research that characterize the stiffness in the knee joint in patients with crouch gait are generally missing (in particular the data for parameter peak knee flexion angle and its dependence on initial contact). Lack of such data indicates the possibility of further development and research in this direction.

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