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The Effect of the Complex Neurosensorimotor Intervention on Children with Cerebral Palsy

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Abstract— The paper analyses the longitudinal effect of the complex sensorimotor interventions on children with cerebral palsy. For a period of nine months, the research involved 48 children at the age of 10–15 years with the diagnosis of cerebral palsy. Individual complex sensorimotor interventions, each lasting for 25 minutes, were applied to children four times per week. The Gross Motor Function Measure Test (GMFM-88) was used for the testing. The research results revealed that there exists dependence of sensations on the type and form of cerebral palsy: superficial, deep and combined sensations are most disordered for children with the dyskinetic tetraplegic form of cerebral palsy ($p<0.05$). The research also revealed that when assessing the development of the gross motor function of children with cerebral palsy, their motor development delays in comparison to their peers, especially in cases of the surveyed with the dyskinetic tetraplegic form. The results of the investigation of sensations of the children with cerebral palsy nine months later remained unchanged, even though the research results revealed slight improvement of the gross motor function ($p>0.05$).

Keywords: *cerebral palsy, complex physical therapy, sensorimotor intervention.*

I. INTRODUCTION

Cerebral palsy (hereinafter referred to as CP) is one of the most frequent neurological diseases of children (Becheva et al., 2017). The spread of cerebral palsy throughout the world is approximately 1.5–3 out of 1,000 born infants (Bjorgaas, 2015). Cerebral palsy is a complex neurological condition occurring after a non-progressing injury in the developing brain, which impacts typical development of child’s movement and posture (Rehab et al., 2016). The brain disorder occurs due to various brain injuries which may happen before the delivery of birth, during the delivery or after it (Liu et al., 2017). Usually, the disorders are motor dysfunction, faulty posture, epilepsy, language disorders; also, co-occurring mental disability, visual, hearing impairments are possible (Žalienė L. et al., 2018; Liu et al., 2017).

The diagnosis of cerebral palsy is stable; however, it is not unchanging: after choosing a proper, continuous treatment, the severity of CP changes to improve. Most often, CP causes problems of movement control: poor posture and balance, lack of coordination, weakness and spasms of muscles, abnormal tone of muscles (Asma, 2019). Along with the motor disorders, sensory disorders frequently occur, as well as communication, cognitive and behavioural disorders are observed. Some individuals experience clonuses, too (Virella, 2016.). Even though the most severe disorder caused by CP is the movement disorder, it occurs due to injuries in the encephalon and not due to muscle or medulla injuries. Especially disordered is the control of precise movements, spasticity of muscles increases (Skurvydas 2017; 2011.). Spastic muscles may decrease the motor function, cause pain and additional complications, such as contractures, deformations of bones or injuries of joints (Wolff, 2018). Even though some children may experience only mild movement disorders, others may be unable to perform even the simplest functional activities, such as to sit independently, to hold a head or to eat independently (Rehab et al., 2016). If a child sits independently by the age of 2 years, has no visual impairments, no mental disorders, no epilepsy or clonuses, we can assess child’s future capacities as positive (Orawan et al., 2018).

CP is determined by brain damage which results in higher centres no longer decreasing primitive reflexes. The remaining manifestation of pathological reflexes for too long does not allow forming movement skills and obstructs the development (Mockevičienė, 2013). Some primary models and reflexes of motor skills, such as stretching of the waist, automatic walking, grasping, swallowing and sucking, develop in the uterus. The prenatal injury of brain causes malfunctioning of these reflexes and negatively impacts another stage of the development (Masgutova et. al., 2008). Infants with cerebral palsy experience the manifestation of absence of primitive reflexes, delayed occurrence and non-disappearance of them (Zafeiriou, 2004). Such reflexes are called pathological. Infants’ primitive reflexes are being initiated by external and internal stimuli; they support an entire complex of human’s movements, skills and even behaviour. The reflex response has two purposes: 1. protective and 2. lays a firm ground for the inner control of movements and development of cognition. Initial movements of a neonate help higher structures of the nervous system develop. Such movements are an essential basis for the development of the motor area and must become integrated into a higher system of movement control (Masgutova 2012). Primitive reflexes are one of the earliest, simplest and most frequently used tools for child neurologists to assess the central nervous system of infants and little children.

Infants' psychomotor and children's motor development is closely related to the system of sensations and depends on a possibility to get sensory information from environment through various channels of senses (vision, hearing, tactile sensing, proprioception etc.). It is clear what significance is given to the senses, especially hearing and vision. Vision helps a child to see people, objects of environment present near, how they look like, what is their colour, shape, size. Through hearing, a child gets acquainted with a diversity of sounds. Through skin, the temperature of environment, objects, characteristics of substances are felt. The sense of proprioception helps a child to feel the body position in space, to get acquainted with one's own body. A kinaesthetic sense helps to perceive the direction of a movement. Through the channels of senses, sensory information reaches the brain. An ability to perceive these triggers, to recognise and interpret them forms. The obtained information is transferred into specific images which form the view of the surrounding world to a child (Bartkuvienė, Semenišina, 2003).

Sensory disorders may obstruct normal development of a child. A blind child starts sitting, crawling and standing later because has no sufficient motivation to move. A hearing-impaired child faces difficulties when receiving auditory information and managing the language. The said disorders usually co-occur with balance disorders. Due to the proprioceptive sensory disorder, the function of cognition of body parts and their position in space becomes disordered. A changed sensitivity of skin obstructs child's better cognition of environment, characteristics of objects, awareness of one's own body. Hypersensitive children react with fear to touching, water procedures, dressing. Hyposensitive children are passive because they have no response reactions to a trigger (Bartkuvienė, Semenišina, 2003).

Children with cerebral palsy are characteristic of disorders of sensations and processing of obtained sensory information, decrease of cognitive skills. It depends on the sensations how a child feels one's own body, how perceives the scheme of the body, the position in space, the distance, the speed of movement, the strength. In order the child performed a voluntary movement, it is necessary that an impulse from the CNS through motor wires reached the muscles. Feedback is necessary, too: specific information must reach the CS via the sensory wires, i.e. to inform about the results. Normal functioning of the CNS evokes normal movements; the information on the movements is supplemented with sensory experiences and further transferred to the CNS, where continuous models of movement performance form. The disordered performance of the CNS in children with cerebral palsy evokes an incorrect movement; it results in receiving inadequate sensory information by the CNS, where it is being registered in the brain zones related to the motor behaviour. Therefore, during the physical therapy (PhTh) procedures, when working with children with cerebral palsy, it is important to form a correct movement or to correct the existing one to qualitatively change the information transferred to the CNS, which in its turn impacts the feedback information. During the PhTh procedures, most of the attention is paid to the performance of a movement and retention of a body position, regardless importance of sensory information. Therefore, research on the sensations of children with cerebral palsy remain relevant and require more detailed investigation. This enabled setting a draft hypothesis having it that purposeful and systematic application of physical therapy makes a positive effect on the development of sensations and gross motor skills of children with cerebral palsy.

The aim of the research is to assess the effect of physical therapy on the development of senses and gross motor skills of 10–15-year-old children with cerebral palsy.

II. RESEARCH METHODS AND ORGANISATION

A. *Research participants*

The research was organised and carried out in a special school. The investigation involved 48 children with cerebral palsy attending special schools. Individual PhTh procedures lasting 20–25 minutes 4 times per week were being applied to the surveyed. The senses of the surveyed and the assessment of their gross motor skills were conducted two times per school year (in September/ May). The investigation was carried out having approval from the managing bodies of the institution and parents (foster parents) of the surveyed.

B. Research methods

Testing (assessment of the body movement function, assessment of sensations). The ***Gross Motor Function Measure Test*** (GMFM-88) was used to assess the level of the development of the gross motor function and the change of the body movement function in children with cerebral palsy. This is a standardised test designed to assess the changes of the body movement function over time. The development of children lying and rolling over (A), sitting (B), crawling and kneeling (C), standing and walking (D) and running (E).

The ***Methods for Examination of the Sensory Function according to Schmitz*** (1988) were employed to examine and assess the sensations. These methods are intended to examine and assess the superficial, deep and combined sensations. The following were tested during the investigation: type of the caused sensation, amount of the examined parts of the body, degree of sensitivity (feels nothing, decreased sensitivity, increased sensitivity, delayed response, normal sensation, hypersensitivity). In the course of the investigation, children were blindfolded so that they could not see a trigger. Before examining the surveyed, their language, cognitive, orientation skills were found out. Those children who could not speak (3 out of 48), indicated the trigger with their hand or reflex reactions, face expression were observed instead of a verbal response. In the course of the investigation, the child must be awake, not tired, focused. First of all, the superficial sensations (acute and dull pain, temperatures, senses of touching, pressing) were examined; later, the deep (movement and position senses) and combined (localisation of touching, differentiation of two points, stereognosis, barognosis, graphasthesia and facture) sensations were investigated. The following means were used during the examination: a pencil with a sharp and a dull ends; glasses with hot (approx. 40 ºC) and cold (approx. 10 ºC) water; scissors, a pencil, a key, a small spoon, a clothes-peg; a soft handkerchief; several small bags of different weigh but same look; pieces of velvet, terrycloth and cotton velvet fabric. Sensations of all types were assessed in a 5-point scale system:

- 1 point. No sensing at all – no response, no reaction;
- 2 points. Inaccurate sensing – not matching the trigging;
- 3 points. Increased sensing – increased sensitivity and reaction;
- 4 points. Weakened sensing – delayed reaction or response;
- 5 points. Normal sensing – accurate response;
- 0 points. Performance of the test was not considered when the surveyed would react ambiguously, contradicting the sensation.

3) **Mathematical statistics**. The analysis of statistical data was carried out using the software SPSS. The arithmetic mean, standard deviation, standard error of the mean and Pearson correlation coefficient (*r*) were calculated. Reliability of the difference between arithmetic means was found using Student's *t* criterion.

III. INTERVENTION

An individual PhTh programme meeting individual needs was designed for each surveyed child. The individual PhTh programme was being applied to achieve maximally normal or lacking movements, to correct incorrectly performed components of a movement; motor behaviour; motor functions were being developed; functional independence was being stimulated by applying compensatory technologies; secondary disorders were being reduced by rendering correct biomechanical body positions which protect from deformations.

Two goals were set for the individual PhTh procedures: functional and general. The functional goal was set with regard to the level of development of existing movements, movement disorders and linked to a particular activity. General goals were needed to achieve the functional goal, to correct disordered movements and reduce the progressing of secondary disorders. While practicing individual PhTh activities, both active and passive movements were being performed, coordination and balance were being trained.

In the course of the individual PhTh procedures, sensory systems of the surveyed were being activated according to individually designed programmes. The touching while stroking, feeling, massaging as well as awareness of weigh while grasping objects of different sizes, weighs were being encouraged during those procedures. Deep sensations were being activated through stretching, deep pressing; the vestibular system was being developed while turning round and swinging back and forth.

IV. RESEARCH RESULTS

48 children with cerebral palsy took part in the investigation. The GMFCS classification distributed in the following way: II = 14 (29%), III = 22 (46%), IV = 10 (21%) and V = 2 (4%). The demographic data of the participants is presented in Table 1.

TABLE I. DEMOGRAPHIC CHARACTERISTICS OF THE PARTICIPANTS (N = 48)

	Characteristics	**Results**
1	***Age (years)***	12.92 ± 1.57 max=15; min=10
2	***Sex***	
	Girls	20 (42%)
	Boys	28 (48%)
3	***Characteristics of the disease***	
	Week of birth	
	< week 37	32 (67%)
	Week 37 <	16 (33%)
	Multiple pregnancy	2 (4%)
	Singleton pregnancy	46 (96%)
	Epilepsy	14 (29%)
4	***CP form***	
	Spastic hemiplegia	16 (33%)
	Spastic diplegia	19 (40%)
	Dyskinetic tetraplegia	9 (19%)
	Ataxic	4 (8%)
5	***GMFCS***	
	Level 2	17 (35%)

	Level 3	11 (23%)
	Level 4	12 (25%)
	Level 5	8 (17%)
6	***Language***	
	Mild language underdevelopment	28 (58%)
	Severe language underdevelopment	8 (17%)
	Moderate language underdevelopment	12 (25%)

NOTE. Values are mean ± SD or n (%).

The data of all surveyed relatively divided into groups according to the clinics allows drawing an assumption that superficial, deep and combined sensations differ depending on the form of CP. Therefore, we present a more detailed analysis of the groups of senses.

The analysis of investigation of the sensations demonstrated that superficial sensations in all surveyed groups were most disordered for the surveyed with dyskinetic tetraplegia (see Fig. 1). The results of superficial sensations for this group are the lowest. However, after calculating the Student's coefficient, a statistically significant difference was found only between the surveyed with tetraplegia and the surveyed with spastic diplegia and ataxia (t=13.1527, p=0.001 and t=3.2014, p=0.033, respectively).

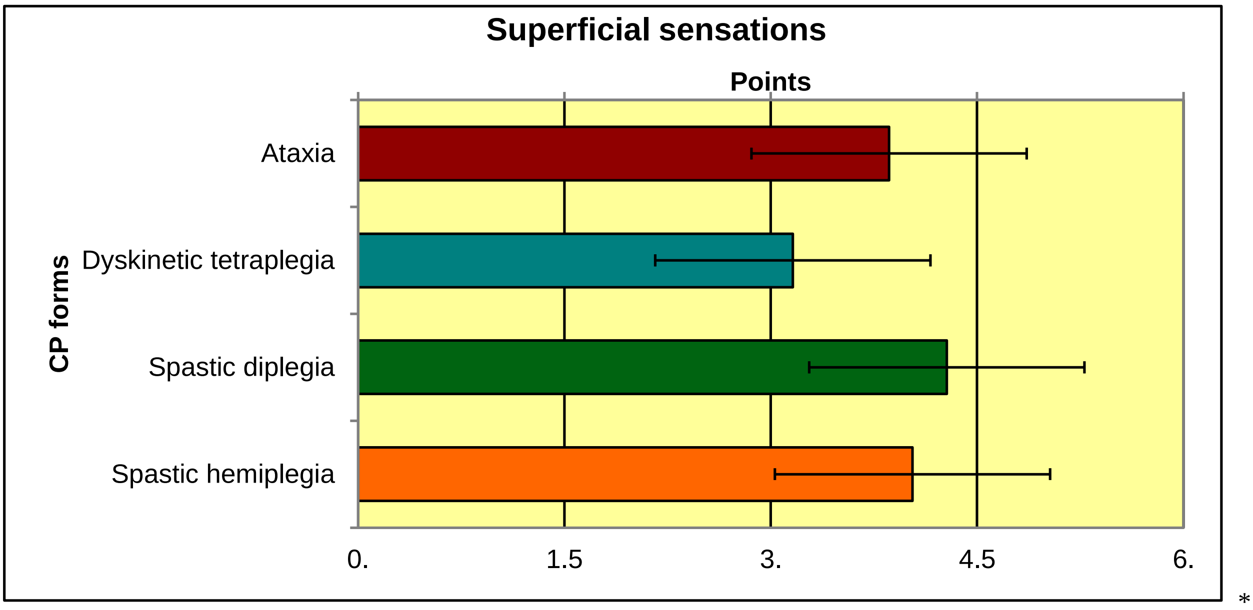
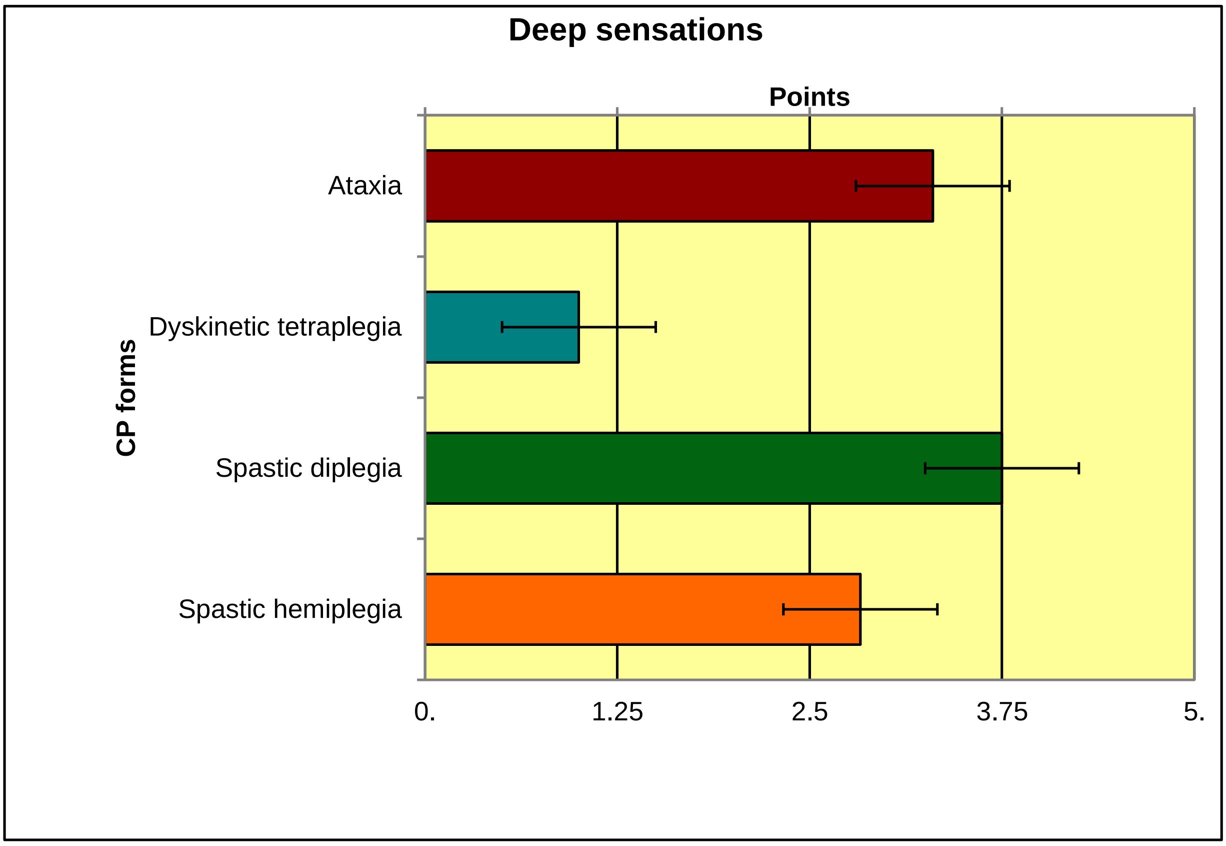


Figure 1. Distribution of the means of points for superficial sensations according to the forms of CP.

Note: * - $p<0.05$.

When exploring the results of superficial sensations of the surveyed with the hemiplegic form of CP, we found out that these sensations were poorer that those of the surveyed with spastic diplegia, even though no statistically significant difference was observed (see Fig. 1). Even though the surveyed with spastic hemiplegia are attributed with the easiest form of CP, an assumption that such results of the investigation of superficial sensations could be influenced by more severe disorders of all types of sensations on the affected side of the body can be drawn.

As the results of investigations of the sensations showed, the surveyed with spastic tetraplegia had deep sensations most disordered (see Fig. 2). A statistically significant difference was found in comparison of this group with other groups of the surveyed: between the surveyed with spastic tetraplegia and spastic hemiplegia it was t=6.3333, p=0.003; between the surveyed with spastic tetraplegia and spastic diplegia it was t=9.5263, p=0.001; between the surveyed of spastic tetraplegia and ataxic form of CP it was t=7.000, p=0.002. Such results could be influenced by passively moved parts of the body as well as unawareness of the direction of a move and position of articular joints. Statistically significant differences between other groups of the surveyed were not found.



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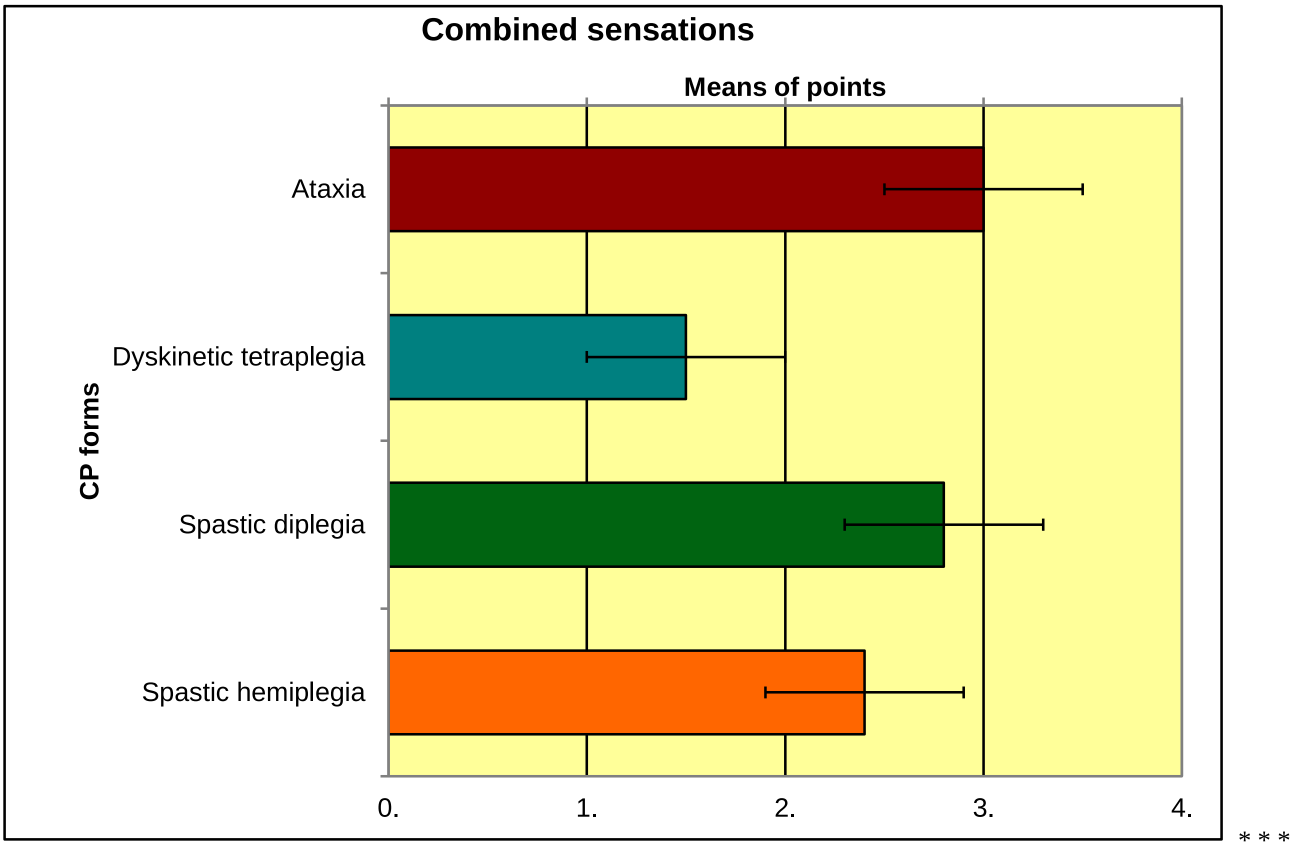
Note: ** - p<0.05.*

Figure 2. Distribution of the means of points for deep sensations according to the forms of CP.

The research results showed that the surveyed with spastic diplegia had the best deep sensations (see Fig. 2).

When comparing the data of the investigations of combined sensations of the children with the ataxic form of CP, we observed that they had the best combined sensations (see Fig. 3). Despite that, a statistically significant difference was observed only between the surveyed with the ataxic form of CP and the surveyed with spastic tetraplegia (t=4.4014, p=0.012).



***Note**: * - p<0.05.*

Figure 3. Distribution of the means of points for combined sensations according to the forms of CP.

The results in terms of the combined sensations of the surveyed with spastic diplegia and spastic hemiplegia were practically identical and much better than those of the surveyed with spastic tetraplegia, even though a statistically significant difference was observed only between the surveyed with spastic diplegia and the surveyed with spastic tetraplegia (t=3.3349, p=0.029).

Summing up the data on the investigation of the superficial, deep and combined sensations and the analysis of them, we could observe that the combined sensations are most severely disordered in all investigated groups of the surveyed. When comparing the means of the points in terms of the data on investigation of the sensations of children with dyskinetic tetraplegia with those of children with other forms of CP, we observe that the means of the points in terms of superficial, deep and combined sensations are the lowest ($p<0.05$).

The analysis of the data of investigation of the sensations before and after the individual procedures of physical therapy showed that the results of investigation of the sensations remained unchanged throughout the nine months. Thus, even though being purposeful and intended for stimulation of the sensations, PhTh procedures that lasted nine months had no direct effect on the change of the results in terms of the sensations of the surveyed independently from the form and type of cerebral palsy.

The analysis of the data of gross motor skills (GM) showed the changes in motor development of the surveyed after the PhTh procedures that lasted nine months. The largest change in the gross motor skills was observed in the group of the surveyed with the ataxic form of CP (see Fig. 4). The GM of this group of the surveyed increased by 2.1 %.

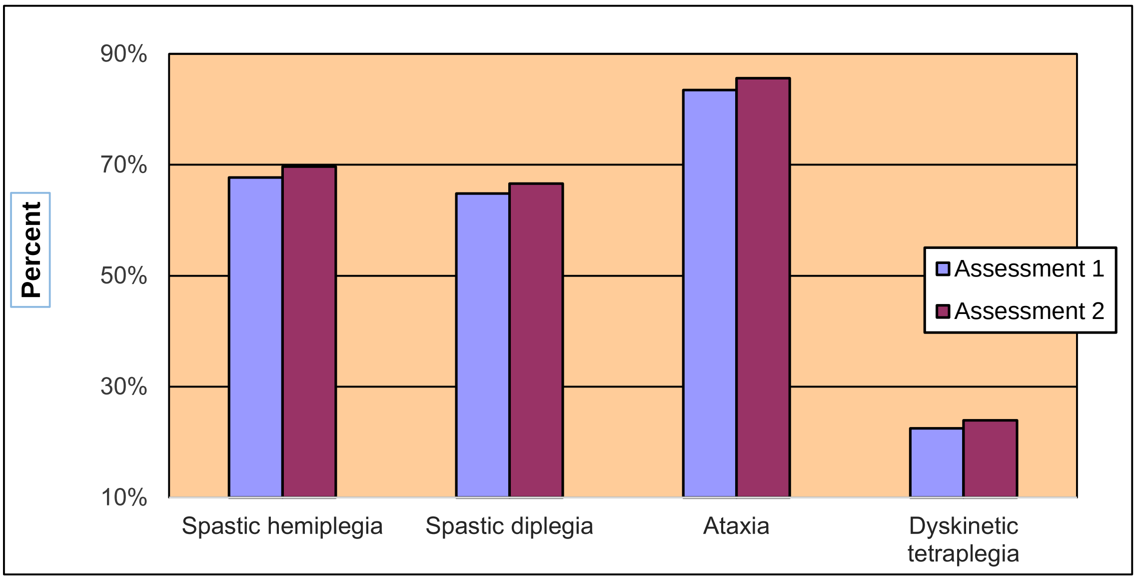


Figure 4. The change of gross motor skills by percent.

After the PhTh procedures, the results for the surveyed with spastic hemiplegia improved by 2 %. The data of GM changed less for the surveyed with the spastic diplegia form (see Fig. 4). Their GM results after the PhTh procedures increased by 1.8 %. Gross motor skills of the surveyed with dyskinetic tetraplegia form changed the least (see Fig. 4). The GM results of these surveyed increased by 1.4 %.

The results achieved in the motor skills areas in the general goal scale are an important component of the GM change. The chosen areas of movement development in the general goal scale are very closely connected to the implementation of the functional goal. They are chosen depending on the functional and general goals set for the disabled person and also with regard to the level of movement development and need for functional movements of the surveyed, also depending on the age of the surveyed. After the PhTh procedures that lasted nine months, not only the GM but also the percentage manifestation data of the general goal scale changed for all surveyed.

The most expressed improvement in the results of the general goal scale was for the surveyed with the ataxic CP. The data of the goal scale for these surveyed increased even by 4.2 % (see Fig. 5).

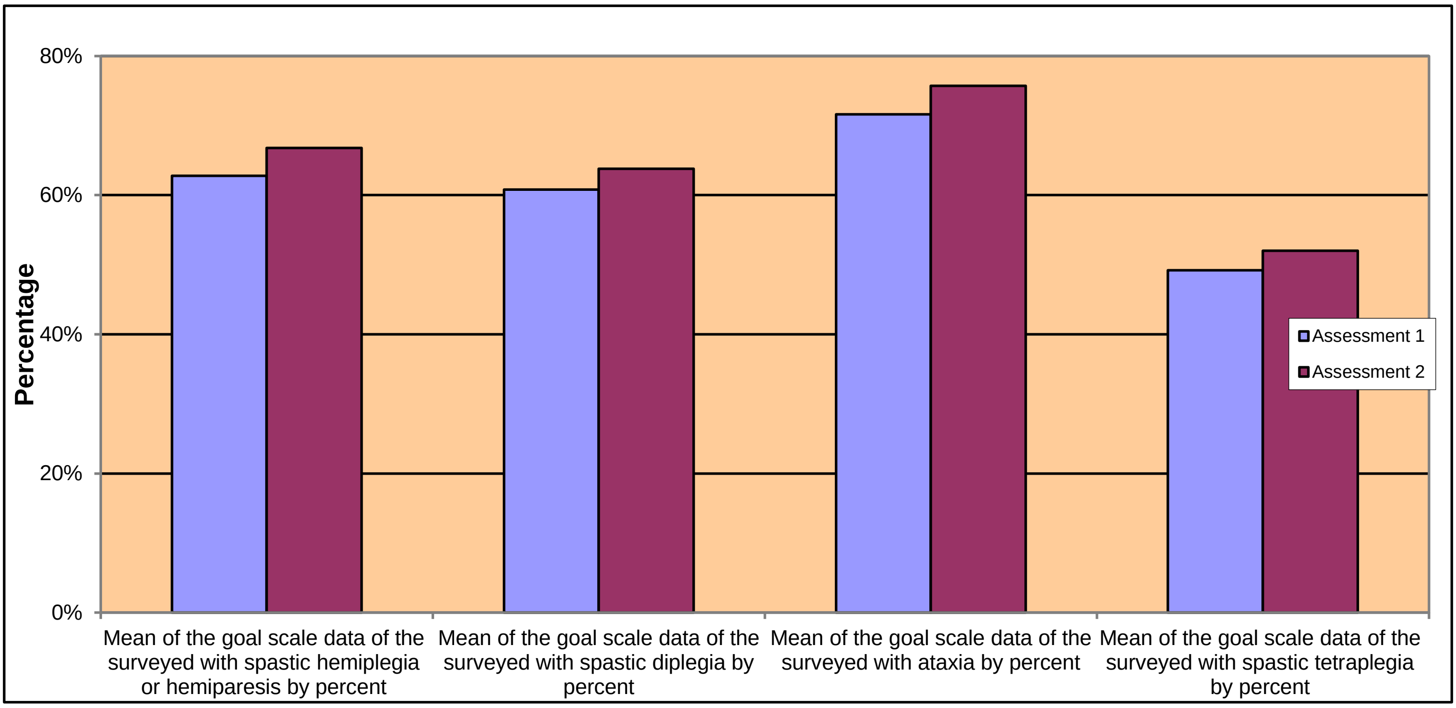


Figure 5. The change of the general goal scale by percent.

Lower results of the general goal scale were observed in the case of the surveyed with spastic hemiplegia or hemiparesis (see Fig. 5). The results of the goal scale for this group of the surveyed increased by 4 %; the results for the surveyed with the spastic diplegia form changed by 3 %. The research data demonstrated that the results of the general goal scale for those ill with spastic tetraplegia changed the least. They increased by 2.8 % (see Fig. 5).

Summing up the results of the research on gross motor skills we could emphasise that in the case of the children with CP a higher change is observed in a chosen goal area rather than in the change of gross motor skills. Thus, the setting of, and striving for, the functional goals during the PhTh procedures is necessary.

Even though the results on the sensations of the surveyed after the PhTh procedures that lasted nine months remained unchanged and the gross motor skills improved, the statistical analysis of the data demonstrated the existing correlations between gross motor skills and investigated sensations (see Table 1).

TABLE I. CORRELATION OF GROSS MOTOR SKILLS AND SENSATIONS.

	Superficial sensations	**Deep sensations**	**Combines sensations**	**Gross motor skills**
Superficial sensations	1			
Deep sensations	*0.88**	1		
Combines sensations	0.65	*0.70**	1	
Gross motor skills	*0.71**	0.66	0.68	1

Note: * – p<0.05.

Having calculated the Pearson correlation coefficient (r), the strongest correlation was found between the gross motor skills and superficial sensations. Thus, the better developed superficial sensations, the better development of gross motor skills. Many scientists (Mockevičienė, Mikelkevičiūtė, Adomaitienė, 2005) emphasise that superficial sensations contribute to faster development of not only child's motor but also cognitive, social progress.

A correlation was observed also between the gross motor skills and deep as well as combined sensations (correlation coefficients 0.66 and 0.68, respectively); however, this connection is statistically insignificant. Therefore, we could draw an assumption that better development of gross motor skills is also better when deep and combined sensations exist.

V. DISCUSSION

Many scientists underline that the children with cerebral palsy are characteristic of delayed processing of sensory information. Ayres (1994) puts is that three types of disorders in processing sensory information for the children with cerebral palsy way occur: lack of modulation, lack of discrimination and decreased reaction to obtained sensory information or registering. These statements are also proven by our research results: superficial, deep and combined sensations of surveyed 10–15-year-old children with cerebral palsy are disordered.

In the case of dyskinetic tetraplegia, all four limbs are affected, but arms are affected more strongly than legs (Budrys, 2003). In the course of the investigation, the surveyed were observed as experiencing spasticity, hyperreflexia, tonic neck reflex. The investigation of the sensations showed that the surveyed with the spastic tetraplegia form had not only characteristic disorders of all types of sensations but also those were more severe in comparison to other forms and types of cerebral palsy. This was impacted by severe mental, cognitive, language process disorders. J. N. V. Daulenskienė (1999) emphasises that due to the severe mental disorder children with dyskinetic tetraplegia have strongly disordered motor functions and sensory functions. Such tendency was observed in our research, too.

Mclanghlin et al. (2005) points out that several severe disorders of sensations, such as differentiation between acute and dull pain, localisation of touching, differentiation of two points and differentiation of toes, occur for children with spastic diplegia. The same tendency was also observed in our research results: children with the spastic diplegia form had severe disorders in differentiation between acute and dull pain, differentiation of two points and identification of movement sensations.

Many authors (Bumin, Kayihan 2000; Budrys, 2003) emphasise that, due to cerebellar hypoplasia, children with the ataxic form of cerebral palsy are characteristic of sensory-perceptive problems, such as awareness of the body, differentiation between left and right sides, differentiation of the body parts, visual perception, astereognosis and apraxia. These statements have been proven by our research, too. The surveyed with the ataxic form of CP were characteristic of delayed combined sensations, severe disorders of the sensations of localisation of pain, movement, touching, differentiation of two points. This could be linked to the instability of waist, asynergy between waist and legs movements, hypotonia, ataxia of both arms and legs, disordered control of the body position.

Hemiplegia manifests in one-sided spastic disorder of motor skills for both limbs. Usually, an arm is more affected than a leg, the right side more often than the left (Budrys, 2003). The pyramidal symptoms, such as spasticity, increased tendon reflexes, Babinski pathological reflex, weakness of some muscles, disordered fine motor skills, manifested in the course of the investigation for the surveyed with spastic hemiplegia. For some surveyed, related movements of the affected arm were observed when making movements with a healthy arm. In the case of children with identified more severe hemiplegia, mild neurological (increased tendon reflexes) or functional (insufficient fine motor skills) features could also be observed on the "healthy" side. It is an obvious feature of bilateral brain dysfunction (Budrys, 2003).

The investigation of the senses showed that the surveyed with hemiplegia had disorders of complex sensations characteristic to cortically affected limbs: localisation of touching, differentiation between two points, stereognosis. These disorders are characteristic to the "healthy" side as well, though not so severe. The affected arm is also characteristic of barognosis, graphesthesia disorders; whereas for the "healthy" side these disorders are not so severe or are normal. The deep sensations of movement and body position are similarly severely disordered. The surveyed were not aware of the position of articular joints, hardly identified the direction of a performed movement, even though a larger part of the surveyed differentiated right and left parts of the body. The same evidences are also presented by V. Budrys (2003) underlining that, due to the affected cortex or sub-cortex, complex sensations, such as localisation of touching, discrimination, stereognosis, touched factures and deep sensations, become disordered.

In order to help the child normally develop as early as possible, it is necessary to identify the child's problem as early as possible. Investigations carried out by D. Mockevičienė (2005) have proven that physical therapy correction for children with cerebral palsy must be applied as early as possible. The scientist emphasises that the methods of physical therapy applied in later age stages have no proper effect and are more a kind of prophylaxis of secondary disorders. This is proven by our research, too: a very insignificant change of the gross motor skills was observed during the investigation. On the other hand, could emphasise the setting of functional goals of the gross motor skills. As our research results demonstrate, in the case of the children with CP, a larger change is observed in a chosen goal area rather than in the change of development of the gross motor skills. Thus, the setting of, and striving for, the functional goals during PhTh procedures is necessary.

The processes of processing sensory information may be impacted by the movement disorders and vice versa. As the results of the conducted investigation show, even though the results of the sensations of the surveyed after the PhTh procedures that lasted nine months remained unchanged and the gross motor skills improved, the existing correlations between gross motor skills and investigated sensations were found out. Thus, when the processing of sensory information is better, the gross motor skills develop better. We would suppose that such dependence is highly important in early age and a proper sensory trigger would stimulate the development of the gross motor skills and vice versa, motor development would stimulate the processing of sensory information.

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CONCLUSIONS

- The dependence of the sensations of the surveyed children with cerebral palsy on the type and form of cerebral palsy was identified: superficial, deep and combined sensations were disordered most of all for the children with the dyskinetic tetraplegic form of cerebral palsy ($p<0.05$). The research data showed that the least affected sensations were of the children with the spastic diplegic form of cerebral palsy.

- Having assessed the level of development of gross motor skills of the children with CP, it was found that the development of gross motor skills of the surveyed is delayed in comparison to that of their peers. The highest results in relation to the gross motor skills were attributed to the surveyed with the ataxic type of CP; the lowest results were of those surveyed with the dyskinetic tetraplegia form.
- The analysis of the investigation of the sensations before the individual procedures of physical therapy and after them showed that the results of the investigation of the sensations throughout nine months remained unchanged. Thus, even though being purposeful and intended for stimulation of the sensations, PhTh procedures that lasted nine months had no direct effect on the change of the results in terms of the sensations of the surveyed independently from the form and type of cerebral palsy, even though the research results showed slight improvement in the gross motor skills ($p>0.05$) after the procedures of physical therapy.

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