SUMMARY

Purpose. The study defines the overall motor performance in children with cerebral palsy, which defines their latent motor space.

Methods. The study was conducted on a sample of 80 children aged 6 to 16 years. Only children with cerebral palsy attending primary schools with equivalent educational standards were included in the research.

Results. A discriminant analysis confirmed that children with cerebral palsy differ in the latent structure of their motor space depending on the diagnosis of cerebral palsy (the type of cerebral palsy). At common motor space, children with different types of cerebral palsy have a distinction. The comparison of three groups/ types of cerebral palsy have shown two discriminative functions, first we called function of common motorics, second function of maturity.

Conclusions. The study confirmed the impact of individual motor components on the formation of motor space. The latter also comprises other dimensions of the broader neuro-therapeutic spectrum. The type of cerebral palsy, causing individual neurological deficits, determines the differences in motor space.

KEY WORDS: motor performance, motor skills and abilities, cerebral palsy
INTRODUCTION

Due to the damage to their central nervous system, children with cerebral palsy exhibit noticeable motor impairments. Their diminished motor performance may be reflected in the awkwardness of movement, posture and balance disorders, excessive muscle tension, etc. (Baxter, 2006). Numerous associative brain connections may also cause problems in more demanding cognitive, emotional and social functions (Carr & Shepherd, 2000).

The elements of fundamental movement are the same in all children; their development is the basis for the development of higher functions (Durward et al. 1999). A child who does not pass through the development phase of perceiving their own body is left with a permanent deficit in body perception (Dolenc-Velickovic, 2010).

Children with cerebral palsy have, in addition to motor impairment, problems that further impede their learning processes: in memorization, attention, orientation, graphomotor skills (Dolenc-Velicković, 2010, Eliasson et al. 2004). Also present are impairments affecting vision, and hearing and speech language disorders (Gage, 2006).

Defining the basic concepts of the study

Motor development is not an isolated process, but one which takes place in close interaction with the development of cognitive, affective and emotional areas influenced by internal and external factors (Gallahue & Ozmun, 1998), Dolenc-Velickovic, 2010).

Motor performance of children with cerebral palsy is different due to the effect of pathophysiological factors. To a growing child this may present an obstacle in forming peer relations (Gallahue, 2010). Many authors emphasize the role of motor development in the overall process of human development (Dolenc-Velickovic, 2010, Geralis & Ritter, 1998, Jekovec-Vrhovsek, 2010).

Postural deviations play an important role in the motor development of children with cerebral palsy. Their academic and personal success is often conditioned by their motor maturity and system sophistication (Geralis & Ritter, 1998).

The present study investigates the motor performance of children with cerebral palsy, the development of their motor skills and abilities related to the broader field of rehabilitation. The aim of the research is to thoroughly investigate the factors influencing the formation of motor skills in children with cerebral palsy.
Motor abilities

Motor abilities determine one’s motor expression; they are a natural endowment (Jekovec-Vrhovsek, 2010). They depend predominantly on the level at which different control systems operate in the central nervous system.

On the whole, motor abilities are innate; a certain level of development can be improved by motor learning. Each individual has their own schedule of development and maturation of motor abilities. This should be taken into account also in children with cerebral palsy, where therapy can not completely compensate for a normal development. The mechanisms stimulated by therapy cannot substitute for normal functioning, development and sophistication of motor abilities. Motor abilities are dependent predominantly on genetic factors, personal experience and environmental effects; and they are relatively stable (Miller & Bachard, 2006). For the purposes of this study, a nomothetic classification of motor abilities was used (Jones & Barker, 1999): flexibility, strength, coordination, speed, balance, and precision.

Flexibility is the ability to change the direction of the movement of the body or its parts with appropriate speed and accuracy. Basmajian and Wolf (Magill, 1998) define flexibility as the ability of the muscle to relax and yield to a stretch force.

Strength is the ability to complete a movement with maximum force in the shortest time possible. It is the ability of the body to overcome different resistances connected with the ability of rapid contraction of the muscles involved (Miller & Bachard, 2006).

Coordination is a complex motor ability, integrated into each element of movement. It constitutes the link between balance, speed and flexibility (Magill, 1998). It requires a coordinated action of the sensory and motor systems.

Speed is the ability to complete a motor task by moving the limbs (Pistotnik, 1999). What is important here is the reaction time required from the initial stimulus to the final stage of the beginning of movement. Balance is the ability to maintain body equilibrium in different positions, by continuously adjusting the body to counteract the force of gravity (Jones & Barker, 1999). The body position against the force acting on the body is adjusted by muscle contraction and relaxation. In the case of cerebral palsy (Scherzer, 2001), the sense of balance is often impaired and balance reactions are unsatisfactory or even absent. The process of motor development in children with cerebral palsy is different due to their neuro-developmental characteristics. It is slower and is accompanied by the occurrence of several compensatory mechanisms (Scherzer, 2001).
Precision is the ability to perform a graduate and precise movement while maintaining the capacity to reach the final goal (Magill, 1998). This is a very sensitive psychomotor ability, especially when influenced by various emotional states.

**Motor Skills**

Motor skills represent the motor knowledge acquired through the process of learning and training. They are the already elaborate, sophisticated skills, the result of motor learning and the learned bases for a correct completion of motor tasks (Miller & Bachard, 2006).

Motor skills are defined as the human ability to achieve a result with maximal reliability and minimal consumption of time and energy. As skills of specialized movement they represent the peak of one’s motor development (Gage, 2006). Motor skills in all their sophistication require a high degree of neuro-motor control, which is lacking in patients with cerebral palsy (Thomas et al. 2003).

Motor skills may be less developed due to diminished conduction of sensory and motor impulses and a primitive spinal control. The reason for this is poor and incomplete myelination of the descending neural system and a lower number of neurons in the higher nerve centres. Riggs, Keogh & Sugden (by Magill, 1998) describe human motor behaviour as comprising three categories: locomotion, manipulation and stability. These are the bases for the formation of motor skills.

Locomotion is closely associated with stability. The fundamental aspects of stability must be established before locomotion begins (Gage, 2006). Many motor skills, such as walking, running, jumping, etc., are basic means of locomotion.

Stability/postural control is one of the basic requirements of human movement. It represents a fundamental movement phase of each motion and is part of all manipulation and locomotion actions. Stability includes the elements of balance and the ability to vary the movement and body posture.

Manipulation requires good control of muscular strength and fine motor control. It is established at a later stage, when stability and locomotion have already been adequately developed. In hemiplegia and tetraplegia in particular, the arms are poorly developed and fine motor skills are impaired (Scherzer, 2001).

**Cerebral palsy**

Cerebral palsy is a general medical term for a variety of neurological signs and is not a disease or illness in the usual medical sense (Miller &
Bachard, 2006). The disorder or damage of the brain does not grow and does not spread to other brain areas.

It is a term used to describe motor deficits resulting from brain damage in early childhood (Scrutton, 2004). Brain damage affects the motor system and results in poorer ability of motor coordination and balance, in the presence of abnormal motor patterns or in a combination of these disorders.

In addition to the perceivable and compulsory motor disorders, other disorders may also be present: epilepsy, hyperactivity, mental impairment, attention deficit disorders, learning disorders, difficulty swallowing and chewing, etc. Most children with cerebral palsy are classified on the basis of the affected body part. Ingram was the first to propose a comprehensive classification of cerebral palsy (Baxter, 2006), which is still valid today (hemiplegia, bilateral diplegia, ataxia, and other forms). Modern medicine has completed and simplified Ingram’s classification according to the types of movement (spasticity, athetosis, hypotonia, ataxia, mixed forms).

**Hypotheses**

The hypothesis, formed in accordance with the research objective, is that the latent structure of the overall motor space of children with cerebral palsy differs depending on the individual type of cerebral palsy and determines the children’s motor performance.

**METHODS**

The sample consisted of 80 children with cerebral palsy attending years 1 to 9 of primary schools of equal educational standards. It included children with neurological signs of cerebral palsy, classified into the following categories: hemiplegia, diplegia, other/mixed forms. The sample consisted of more girls (53.8%) than boys (46.2%); the age structure was between 6 and 16 years. Most children had been diagnosed with hemiplegia (47.5%), with diplegia (33.8%), other/mixed forms (18.7%). 90% of the pupils had regular physical therapy, 56.3% had occupational therapy. In 85% of children the pregnancy had been singleton, 65% of children were born prematurely. The data were collected solely for scientific research purposes and were obtained with the permission of the subjects’ parents.

The study was given a favourable opinion by the National Medical Ethics Committee.
The observed variables

The variables were defined in accordance with the theory of cerebral palsy. The chosen selection of variables included the motor and neurological components influencing the performance of children with cerebral palsy. In the area of motor skills and abilities, the following variables were included: flexibility, precision, balance, muscle strength, coordination, speed, stability/postural control, manipulation and locomotion.

Reliability of motor tests was verified with the Cronbach alpha coefficient and their validity was assessed with a factor analysis. The variables included in statistical data processing reached the levels of interval and ratio scales.

The study also included constant variables from the wider socio-therapeutic areas: gender (female/male), age (in months), diagnosis (hemiplegia, diplegia, other/mixed forms), involvement in occupational therapy, physical therapy (yes/no), singleton/multiple pregnancy, mature/premature childbirth.

Measurement tools

For the purposes of the research, a variety of observational, measurement and anamnestic instruments were used to measure, test and evaluate the motor skills and abilities observed in patients with cerebral palsy. To determine the level of motor development, a set of copyright motor tests was used. Due to a series of neurological and physiological factors, children with cerebral palsy represent a population that cannot be adequately tested with conventional motor tests.

For the purposes of the research, a set of motor tests was designed, enhanced and adapted to include a wider population of children with cerebral palsy (of various types). The chosen motor tests took into account the pathology of cerebral palsy and the dynamics of the developed motor performance.

Statistical analysis

The test results were processed with the SPSS statistical software for personal computers. The necessary measurement properties were identified for the measurement instruments used in the study (post festum analyses). The obtained data were analyzed using basic statistical procedures: descriptive statistics, factor analysis, discriminant analysis.
Discriminant analysis was used to determine the differences in the latent structure of motor space. With a linear combination of the manifest predictor variables, one or more discriminant functions were obtained (based on the step-by-step approach). The size of the sample meets the requirements on statistical reliability in the ratio between the number of variables and subjects included in the study.

**Descriptive statistics**

Basic descriptive statistics were applied to the entire sample. The results of descriptive statistics yielded the basic statistical information on the selected variables. The results showed that all of the selected variables of the system can remain in further statistical processing. A two-tailed criterion of significance ($2P$) was used, taking into account the number of degrees of freedom at the alpha risk level set at 0.05.

In descriptive statistics the following values were used: numeral, arithmetic mean, standard error of arithmetic mean, median, mode, standard deviation, coefficient of asymmetric distribution (CA) and coefficient of kurtosis distribution (CK). Variables were standardized, the results varied in the interval between -5 and +5 of standard deviation, therefore the arithmetic means always equal zero. For each variable standard deviation is stated by separate values according to the dispersion of data. Further statistical procedures were carried out with the purpose of motor space distribution. Variables were tested with the Kolmogorov-Smirnov normality test. Statistically significant abnormal distribution of results was 1.914 for the variable of balance, 1.483 for stability, 2.369 for speed, 1.916 for flexibility, 1.751 for locomotion, 2.654 for manipulation, and 1.397 for graphomotor skills. A two-sided significance criterion ($2P$) was used with the number of spatial degrees taken into consideration. Given the number of abnormally distributed variables, the Rankit plot was applied to check normality of all variables.

**RESULTS**

To verify the hypothesis, we used the method of canonical discriminant analysis. It showed which of the manifest variables best discriminate between the groups.

The results of discriminant analysis showed that there was a statistical difference in the latent structure of all of the abilities determining the motor space of children with cerebral palsy, according to the type of cerebral palsy. Pupils with individual types of cerebral palsy differ from each other in the common motor space. The type of cerebral palsy and
its accompanying pathology importantly define the patient’s motor space.

Discriminant analysis was performed to distinguish between three groups of children with cerebral palsy: a group of children with hemiplegia, a group of children with diplegia and a group of children with other/mixed forms of cerebral palsy.

Table 1. Canonical discriminant analysis by type of cerebral palsy (diagnosis) and the latent structure of motor space

<table>
<thead>
<tr>
<th>Function</th>
<th>Eigenvalue</th>
<th>% Variance</th>
<th>% Cumulative</th>
<th>Canonical correlation coefficient</th>
<th>Wilks' Lambda</th>
<th>Chi-square</th>
<th>df</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.164</td>
<td>54.0</td>
<td>54.0</td>
<td>.898</td>
<td>.043</td>
<td>153.047</td>
<td>108</td>
<td>.003</td>
</tr>
<tr>
<td>2</td>
<td>3.545</td>
<td>46.0</td>
<td>100.0</td>
<td>.883</td>
<td>.220</td>
<td>73.427</td>
<td>53</td>
<td>.033</td>
</tr>
</tbody>
</table>

The results show that there are significant differences between children with specific types of cerebral palsy. In order to compare the three groups of children divided according to the type of cerebral palsy, we obtained two discriminant functions (Table 1). The value of discriminant functions and their canonical correlation coefficient are sufficiently large. The small value of Wilks’ lambda indicates differences in the discriminant function between the groups. The importance of Wilks’ lambda was tested with a chi-square test, which confirmed its statistical reliability. The functions distinguish well between hemiplegia, diplegia and other/mixed forms of cerebral palsy.

Table 2 shows correlations between the discriminant function and manifest variables of the system. The first function is labeled as the function of the overall motor performance and the second is labeled as the function of maturity.

The functions are hierarchically ordered by their correlation with the discriminant function from the highest to the lowest correlation value. The distribution of the results of the structural matrix for the first function shows that the selected variables of the system: maturity, speed, graphomotor skills, balance, locomotion, coordination, and flexibility are affected by the type of cerebral palsy. They are influenced by the child’s neurological diagnosis, particularly the variable of speed, which occurs most often.

There is also a noticeable impact on these variables: graphomotor skills, coordination, locomotion and balance. The distribution of the results of the structural matrix for the second function reveals that maturity is affected by the type of cerebral palsy. It is influenced by the basic neurological diagnosis, determining the motor failures.
Table 2. Structural matrix of functions

<table>
<thead>
<tr>
<th>Function</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maturity</td>
<td>-.175</td>
<td>.104</td>
</tr>
<tr>
<td>Speed</td>
<td>.157</td>
<td></td>
</tr>
<tr>
<td>Graphomotor skills</td>
<td></td>
<td>.151</td>
</tr>
<tr>
<td>Balance</td>
<td>-.147</td>
<td></td>
</tr>
<tr>
<td>Locomotion</td>
<td>.139</td>
<td></td>
</tr>
<tr>
<td>Locomotion</td>
<td>.135</td>
<td></td>
</tr>
<tr>
<td>Balance</td>
<td>-.133</td>
<td></td>
</tr>
<tr>
<td>Coordination</td>
<td>-.132</td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td>.128</td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td>.122</td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td>.115</td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td>.109</td>
<td></td>
</tr>
<tr>
<td>Coordination</td>
<td>.103</td>
<td></td>
</tr>
<tr>
<td>Flexibility</td>
<td>.103</td>
<td></td>
</tr>
<tr>
<td>Graphomotor skills</td>
<td></td>
<td>-.102</td>
</tr>
</tbody>
</table>

The variable of maturity acts as an important factor in both functions. It thus proves its impact on the construction of the neuromotor system in children with cerebral palsy. The remaining variables do not achieve sufficient reliability to affect the division.

Group centroids (Table 3) represent the average values of the canonical variables for both groups. The direction of the first discriminant function is positive for the group of children with diplegia and for the group of children with other/mixed forms of cerebral palsy. The direction for the group of children with hemiplegia is negative. The direction of the second discriminant function is positive for the group of children with other/mixed forms of cerebral palsy and negative for the groups of children with hemiplegia and diplegia.

Table 3. Group centroids

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Function</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemiplegia</td>
<td>-2.089</td>
<td>-.511</td>
<td></td>
</tr>
<tr>
<td>Diplegia</td>
<td>2.312</td>
<td>-1.374</td>
<td></td>
</tr>
<tr>
<td>Mixed forms</td>
<td>.852</td>
<td>3.701</td>
<td></td>
</tr>
</tbody>
</table>

The selected system of variables was 100% significant in all three groups of children, which indicates complete divisibility of the chosen
CONCLUSIONS

Due to disturbances in the functioning of the central nervous system, cerebral palsy causes delays in motor development. Consequently, there is a lower conductivity of the sensory and motor impulses and a primitive spinal control of muscular responses (Thomas et al. 2003). Children with cerebral palsy need a suitable therapeutic program and many opportunities for practice and training.

They must be provided with sufficient opportunities to acquire new motor experiences, which they can use to test themselves and to experience progress in the development of a specific skill. During the process of maturation, most of the straightening reactions are gradually integrated into - in terms of development - more complex equilibrium reactions.

However, in cerebral palsy this integration is never entirely sufficient. Cerebral palsy prevents the movement patterns from overlapping and complementing each other in the process of development. Patients’ movement exhibits lack of stability and poor graduation (Siebes, 2001).

There are certain limitations to the study that need to be considered in the interpretation. The sample of children with cerebral palsy was relatively small due to their dispersion and the process of obtaining parental consent. A larger sample and representation of different forms of cerebral palsy (hemiplegia, diplegia, tetraparesis, athetosis, ataxia, etc.) would enable a more detailed division of motor performance. The sample could not be designed to include younger or older children exclusively. It was necessary to design a wide range of tests ranging from simpler to more demanding tasks.

The selected motor variables do significantly determine a child’s motor performance, but they are selective due to the different types of cerebral palsy. By reason of certain limitations, the statistically already processed motor tests could not be used.

DISCUSSION

In children with cerebral palsy there are differences manifested in the occurrence and maturity of individual motor skills and abilities (Siebes,
2001; Scherzer, 2001; Scrutton, 2004). The cause of this "motor difference" lies in the occurrence and life-long existence of certain pathological reflexes. In normal development, these should gradually disappear or become integrated into more complex movement patterns. In children with cerebral palsy the occurrence of a specific pathology, in terms of less mature forms of motor behaviour, is not necessarily negative. Rather, it is a reflection of the difference in development and at the same time represents a satisfactory and effective substitute for the majority of motor actions (Carr, & Shepherd, 2000).

The study found a statistically significant difference in the latent structure of all the abilities comprising the motor space of children with cerebral palsy in relation to individual type of cerebral palsy. Children with various types of cerebral palsy differ from each other in their common motor space. The type of cerebral palsy and the associated pathology importantly define the children’s motor space. It should be noted that the motor structure of persons with cerebral palsy differs from the motor structure of healthy individuals.

The study brings a new perspective to the understanding of motor skills in children with cerebral palsy. It contributes to the clarification of the theory of motor development of individuals whose process of motor development is different, slower. The survey provides new insights into the development of the motor performance of children with cerebral palsy, in which diagnosis plays an important role. These new findings can be used by therapists who encounter different types of cerebral palsy in the process of rehabilitation. An appropriate neuro-therapy should promote optimal variability of movement patterns with gradual integration of more mature forms of movement.

The study proves the significance of the effect of the specific type of cerebral palsy on motor system development. This also confirms the role of basic neurological diagnosis on the occurrence of certain motor skills and abilities. The presence of a specific diagnosis (type of cerebral palsy) affects and defines the latent structure of the motor space.

REFERENCES


