

Motor skills, cognitive development and balance functions of children with Down syndrome

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Abstract

Introduction and objectives: Motor and cognitive development of children with Down syndrome (DS) is delayed and inharmonic. Neuro-muscular abnormalities, such as hypotonia, retained primary reflexes, and slow performance of volitional reaction, result in difficulties with body balance. The aim of the presented study is to assess the global motor functions and body balance of children with DS in relation to age and mental development.

Material and methods: The study group consisted of 79 children with DS (42 boys, 37 girls), average age 6 years and 3 months \pm 4 years and 6 months. Participants were divided according to age range into 3 groups: < 3 years old, 3 – 6 years old, > 6 years old.

Children were assessed using Gross Motor Function Measure-88 (GMFM-88) and Paediatric Balance Scale (PBS). Psychological diagnosis served to determine the degree of mental development using the Brunet-Lezine Scale for children younger than 3 years old, and the Wechsler Intelligence Scale for Children (WISC) for those who are older than 3 years. Nine children in research group had not been diagnosed by psychologists, which is the reason why the analysis referring to mental development was performed in 70 children (34 girls, 36 boys), with an average age of 4 years and 6 months.

Results: GMFM-88 scores were significantly lower in children with moderate psychomotor delay than in children with mild psychomotor delay, or normally developed children, $p=0.043$. GMFM-88 scores in children with profound mental impairment were lower than in children with mild or moderate mental impairment. There was a statistical significant correlation between GMFM-88 scores and the PBS scores, $r=0.7$, $p<0.0001$.

Conclusions: Motor development of children with Down syndrome from towns and villages in the Greater Poland region is associated with cognitive development, especially in the first three years of life, with the balance functions being closely related to motor skills.

Key words

Down syndrome, motor development, balance scale

INTRODUCTION

Down syndrome (DS) is one of the most common congenital disorders [1], which affects 1 child per 605 live newborns in Poland [2, 3]. Many clinical symptoms of this chromosomal malformation are caused by additional chromosome 21 [2]. The appearance of three instead of two chromosomes is known as trisomy. Extra chromosome 21 leads to such symptoms as: metabolic disorders, tissue dimorphism, internal organs disorders, characteristic phenotype in physical appearance, muscle hypotony and mental retardation [2]. Furthermore, the motor development of children with DS is delayed and inharmonic [2]. For instance, lack or delay in the Moro reflex is an example of retarded neuro-motor development in the first period of life, and is one of the cardinal features of DS [4]. Referring to abilities which are characteristic of infants in the first year of life, there is a delay in gaining a sitting position – 14 month of life (m.l.), instead of 6 m.l., crawling – 12–18 m.l. (instead of 8 m.l.), walking 24–74 m.l. (instead of 10–15 m.l.)

[5, 6, 7]. The age when children with DS achieve gross motor function is at approximately twice the age of performing motor skills by children typically developed [7]. Cognitive development is also delayed among children with DS [8]. A slower rate of such areas of development as intelligence, attention, verbal communication, learning, memory and performing motor abilities is observed [2]. Children with DS are often scored by psychologist as being within the mild to moderated range of mental impairment [8].

The over-expression of genes localized in chromosome 21 is responsible for such dysfunction in the central nervous system (CNS) as: 1) smaller overall volume and smaller amounts and shape of neurons, 2) delay in neural myelination in CNS, 3) pathophysiological processes, such as degenerative processes in CNS, dysfunction of regulation of the neural apoptosis, over-expression of beta amyloid precursor protein (APP) and lower capacity of neurotransmitters [2, 9].

Neuro-muscular anomalies, such as hypotonia, retained primary reflexes, and slow performance of volitional reaction, lead to problems not only with motor functions and cognitive development, but also problems with body balance [10]. This is why children with DS show exaggerated body movements as an answer to destabilized stimulus. Balance reaction is

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additionally problematic due to inadequate co-contraction caused by muscle weakness, mental retardation, dysfunction in sensory integration processes, cartilage hypoplasia, and improper bone density [11].

The aim of the presented study is to assess the global motor functions and body balance of children with Down syndrome from towns and villages of the Greater Poland region, in relation to age and mental development.

MATERIAL AND METHODS

The study was conducted between 2009–2011. The study group consisted of 79 children with DS (42 boys, 37 girls), average age 6 years and 3 months \pm 4 years and 6 months. Participants were divided according to age range into 3 groups: < 3 years old, 3–6 years old, > 6 years old.

The study took place in the Greater Poland region, and comprised patients with DS from towns and villages of the region and attended the Poznań Centre for Rehabilitation and Orthopedic, the 'YES' Association, and the Polish Association of Mental Retarded People 'Koło' in Leszno. The study was approved by the Bioethics Committee of Poznań University of Medical Sciences.

Children were assessed using the Gross Motor Function Measure-88 (GMFM-88), Paediatric Balance Scale (PBS), Kasperczyk Visual-Point Method. Psychological diagnosis served to determine the degree of mental development using the Brunet–Lezine Scale for children younger than 3 years of age, and the Wechsler Intelligence Scale for Children (WISC) for children above the age of 3 years. It was not possible for psychologists to make a diagnosis of the mental development among 9 children in the study group in the same way as the analysis of motor functions performed among the total group of 70 children (34 girls, 36 boys), mean age 4 years and 6 months.

Gross Motor Function Measure-88 (GMFM-88). GMFM-88 scale was primary designed to evaluate change in gross motor function of children with cerebral palsy [12]. At present, 88 items may be used to assess children with DS [7, 12]. Motor functions are grouped in 5 dimensions in GMFM-88: 1) lying and rolling (17 items), 2) sitting (20 items), 3) crawling and kneeling (14 items), 4) standing (13), 5) walking, running and jumping (24 items) [12, 13]. Referring to the guidelines of GMFM-88 assessment for children with DS, the environment should be as familiar to the children as possible, and arranged in such a way to encourage the performance of activities. Thanks to a well-prepared room and appropriate equipment, children performed many tasks spontaneously [12]. Sometimes, several meetings were needed to assess one child, because of the tendency for DS children to have attention deficit. Assessment of each child was completed within one week in order to avoid changing motor function which might appear to be due to the child's development. Each task was measured by observation and scored on a 4-point ordinal scale. Value 0 indicated that a child did not initiate the task, 1 point – performed less than 10% of the task, 2 points – a child partially completed a task (10% to < 100%), 3 points – the child completed the task (100%) [12].

Pediatric Balance Scale (PBS). PBS was administered to children older than 4 years. The rules and equipments

have been described by Franjoine and respected during the assessment. Visual and verbal cues were provided to ensure that the child understood the requested task. Each test session lasted 10 – 20 minutes. Based on the criteria, each of the 14 tasks from the PBS was scored 0 – 4. Fourteen items of PBS enabled examination of functional balance in the context of everyday life. For instance, retrieving an object from the floor or changing from a standing position to sitting. A child who successfully completed all the tasks could gain a maximum of 56 points [14].

Differences in GMFM-88 scores were evaluated according to: 1) degree of mental impairment expressed in WISC among children with DS older than 3 years of age, and 2) Brunet–Lezine developmental quotient among children with DS younger than 3 years of age. The analysis took into account the age of children. Nine children for whom mental impairment was not determined were excluded from data analysis.

Statistical analysis. Data were analyzed using STATISTICA 8.1 (StatSoft). Non-parametric tests were used to analyze the difference between medians in ordinal scales. Mann-Whitney U test was used for comparing 2 independent samples, a few samples which were unrelated were tested using Kruskal-Wallis test with Dunn multiple comparison post-test. Correlation between samples was measured using Spearman's rank correlation. P value 0.05 was considered statistically significant.

RESULTS

Mental and psychomotor development was assessed as normal in 7% of children, mild impairment in 7% of children, moderate impairment in 70%, and profound impairment in 4%. The results of GMFM-88 in relation to age and mental status are presented in Table 1. In the age group of children under the age of 3, none of them had a profound delay in psychomotor development. GMFM-88 scores were significantly lower in children with moderate psychomotor delay than in children with mild psychomotor delay, or normally developed children, $p=0.043$.

Table 1. Gross Motor Function Measure-88 scores categorized by mental development and age of children.

age range	GMFM-88 [%] number (N); median; (minimum – maximum)				P
	Degree of mental impairment/ dilation of psychomotor development according to developmental quotient				
	normal development	mild impairment	moderate impairment	profound impairment	
< 3 years	N=5; 44.57 (36.43 – 81.79)	N=6; 54.33 (13.73 – 64.45)	N=4; 15.76 (5.1 – 31.13)	-	0.043*
3–6 years	-	N=4; 85.39 (79.67 – 95.79)	N=15; 88.46 (64.25 – 98.46)	-	0.72**
> 6 years	-	N=4; 98.91 ^a (96.38 – 100)	N=29; 98.33 ^b (89.47 – 100)	N=3; 83.25 (82.73 – 89.70)	a vs b** 0.28

* Kruskal-Wallis test with Dunn Multiple Comparison Test;

** U Mann-Whitney test

In the group of 3–6-year-old children, there were no children with normal mental development or profound mental impairment. There was no significant difference in

GMFM-88 scores in children with mild mental impairment, compared to children with moderate mental impairment ($p=0.72$) in the age range 3–6 years.

Similarly, there was no significant difference in GMFM-88 scores in children with mild mental impairment, compared to children with moderate mental impairment in children above the age of 6 years. GMFM-88 scores in children with profound mental impairment were lower than in children with mild or moderate mental impairment. However, statistical analysis could not be performed because of the small number of children with profound mental impairment.

Functional balance was assessed in children older than 4 years. There was a statistically significant correlation between GMFM-88 scores and the PBS scores, $r=0.7$; $p<0.0001$ (Fig. 1).

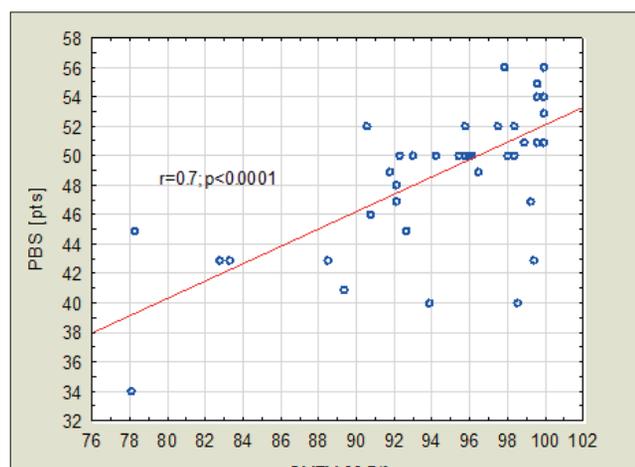


Figure 1. Positive correlation between Gross Motor Function Measure–88 (GMFM–88) scores and balance score (Pediatric Balance Scale, PBS) in children with Down syndrome.

DISCUSSION

One of the most important goals of therapy for children with DS is to develop motor functions and mental skills which allow them participate in social life. This is the reason that motor and mental skills should be measured in order to point out the abilities a child can perform, and indicate those functions that should be developed in the future [15]. Motor functions may be measured very accurately thanks to the GMFM-88. However, motor abilities should be considered in conjunction with mental skills.

In the presented study, a statistically significant relationship was found between motor achievements and Brunet–Lezine developmental quotients in children under the age of 3 years. This may indicate that delay in gaining motor abilities may cause delay in achieving skills in others areas of development, such as social, emotional, communication, cognitive and self–help skills [16]. Especially during the first years of life, the connection between motor and mental development is very strong. Movement is considered the basis for learning new abilities, even cognitive abilities, in the first years of life [17]. Infants and young children obtain knowledge about the world through touching, taking toys into the mouth, and observing [2]. The child's motor skills influences social, language and cognitive experiences, which is why delay in motor development may also cause delay in other areas of development [2].

Similarly, the relationship between motor and mental development may exist in children older than 6 years of age; this association, however, was not as strong as in earlier period of life. The age >6 years is the period of developing motor skills related to coordination function [17]. Coordination is defined as multiple effectors working in connection with motor planning [18]. Children with DS may show difficulties in motor abilities which are related to coordination and alternation. Hypoplasia of *corpus callosum* and the cerebellum is one of the reasons for problems with bilateral motor coordination [19]. Coordination additionally requires concentration and attention, which are aspects of cognitive functioning, which is why children with a mild degree of mental impairment may show better scores in motor task related to coordination than children with moderate and profound degree of mental impairment. The age above 6 years refers to learning sequential motor abilities, such as walking up-and-down stairs with alternating feet, which is more challenging than skills from other periods of life [17].

Other abilities characteristic for this period of life refer to running. The concept of velocity, trunk rotation and flight phase are aspects of movement connected with running, and are problematic for children with DS [19, 20]. To sum up, children older than 6 years who were assessed as profoundly mentally impaired may be assessed worse in GMFM-88 scores than children with mild or moderate degree of mental impairment, because functions from the age range above 6 years require additional motor abilities, such as increasing speed, coordination (swinging arm during movement of the legs, forward movement and controlling balance). Skowroński noticed that children with mild mental retardation, in contrast to children with DS with other degrees of mental impairment, may present motor abilities to the same degree as children with normal cognitive development [21].

Functional balance was another aspect measured. The 14 items of the PBS seemed easy to perform because they are similar to everyday activities, for example: sit-to-stand/stand-to-sit, and reaching forward [14]. Functional balance is defined as the element of postural control that allows a child to perform everyday tasks [14]. A review of balance publications in the literature suggests that children with mild to moderate motor impairment have limited abilities to maintain a state of equilibrium. Etiologies of balance deficits may include neurological and musculoskeletal causes [14]. The relationship between functional balance and motor skills was measured in the study group and revealed that there is highly significant correlation between motor functions scored by GMFM-88 and functional balance. Paediatric Balance Scales scores were significantly higher among children with DS who had higher scores in motor abilities measurement. The influence of motor function scores on balance scores may be interpreted as the fact that a limited movement repertoire causes difficulties in maintaining a state of equilibrium within a given changeable environment. This was also postulated by Kegel [22, 23]. The fewer the variations of movement strategies the children perform, the better the balance abilities they present.

The results of the presented study suggest that therapy of children with DS should consider multiple areas of development. Motor and balance should be taken into account and measured in order to plan appropriate physical therapy. Therapists should map out the goals which will be specific, measurable, attainable, relevant and time-oriented (SMART)

[24]. The setting of appropriate goals by specialists in various fields enable the children to achieve the functions that will be their resource and potential for the future. This is possible thanks to the detailed assessment using an appropriate scale, such as GMFM-88 and PBS, that allow therapists to monitor a child's development.

CONCLUSION

The motor development of children with Down syndrome is associated with cognitive development, especially in first three years of life, and balance functions are closely related to motor skills among such children. Thanks to appropriate motor and balance scales, such as PBS and GMFM-88, it is possible to plan therapy for children with DS and assess the functional abilities which are needed in everyday life. The scales shown in the presented research was used for the first time in children with DS in Poland.

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