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Postural Control in Down Syndrome Subjects

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Abstract

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Objective - The Down's syndrome children present important motor problems which affect static and dynamic balance. Equilibrium represents the capacity of keeping the body steady in standing position as well as the ability to perform usual dynamic tasks (walking, jumping and running) without falling. The objective of this paper is to present by comparison the postural control in Down syndrome subjects and non-disabled persons. Method - Five young Down syndrome subjects, aged 8 to 15 years old, and five normal age-matched subjects were included in the study. Static equilibrium was evaluated on a posturograph (Smart Balance from NEUROCOM) which has a force-plate. Equipment allows time and frequency domain analysis of the centre of pressure of the subjects. Subjects have to maintain upright position as steady as they can for 20 seconds, on the stabilised force-plate in two conditions – eyes closed and eyes open. Results - Analysis of the postural control revealed lower performance in maintaining the upright position from time domain point of view in Down syndrome group. Conclusion - Motor control problems are present in Down syndrome children since birth (hypotonia, low joint stability and joint hypermobility) and impede upon the development of motor control if early rehabilitation is not provided. This characteristic lasts for the whole life of the Down syndrome person.

Keywords: Down syndrome; postural control; posturography.

1. Introduction

Down syndrome (DS) is a chromosomal anomaly caused by an additional chromosome – trisomy 21 and is characterized by important intellectual and adaptive behaviour limitations.

Triplication of the 21st chromosome described by Jacobs and Lejeune is found in all cells of the embryo or only in some of them (mosaicism for the latter condition).

Down syndrome (mongolism) was first described as a syndrome by Langdon Down. Its incidence is of 1/600-700 births and it is the best known dysgenesis. It is responsible for 10% of all severe mental retardation cases.

Significant problems are present in DS, among which neuromotor control and sensory integration. Due to these two factors, postural control and equilibrium are impaired in DS. Children with DS have hypotonia of the limbs (most of the DS children do not walk until the age of 3-4 years), joint hypermobility, persistence of primitive reflexes and decrease in deep tendon reflexes (Jobling, 2004, 2006).

Primitive reflexes are spontaneous, stereotypical, which are present at birth in healthy newborn babies, as a response to a specific stimulus. As normal development occurs, these primitive responses disappear and are replaced by automatic responses (postural reflexes). The latter ones determine variable responses to stimuli in order to maintain upright position and equilibrium during any movements (they prevent falls) (Gentile, 1992).

As the child develops (until the age of 2), different postural reflexes are learnt: righting (ability to have correct orientation of head and body), protective (reactions of the extremity to rapid body displacements) and equilibrium (allow motor control while changing the centre of gravity) (Martin, 1989; Ayres, 1972).

Children with intellectual disability have various degrees of sensory integration. These limitations in using the sensory information impede upon learning, and this is also the case for learning equilibrium.

In DS children, delayed motor development determines delays in postural reactions as well.

Hypotonicity disrupts the feedback loop, essential in perception of the position of the body in space, and also affects the voluntary control of muscles (Woollacott & Shumway-Cook, 1986).

Besides these abnormalities, dysfunctionality of cerebellum and brainstem, poor coordination and time aspects of motor control are also present (Sefort & Spreen, 1979). For this reason, individual therapy for balance and coordination problems is needed not only in early childhood, but also in adolescent life (Connoly & Michael, 1986; Moni & Jobling, 2000).

Sensory integration stands for “the organization of sensory input for use” (Ayres, 1979, 1989, 2005). It is a neurological process which consists in evaluating each sensory input, comparing their congruency and integration of information in order to develop appropriate responses for equilibrium/ motor behaviour.

The Down’s syndrome children present serious deficiencies at the motor and psychomotor levels, which have negative influences on their daily living. These deficiencies should be identified and corrected immediately after identification, so that the children could live closer to normality as early as assessment is available - both measurement of motor function and equilibrium and of the activities of daily living (Uyanik & Kayihan, n.d.).

The Down’s syndrome children present important motor problems which affect static and dynamic balance. Equilibrium represents the capacity of keeping the body steady in standing position as well as the ability to perform usual dynamic tasks (walking, jumping and running) without falling. All these activities, normal for unchallenged children, are real challenges for DS children whose postural control is affected.

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2. Materials and methods

The aim of the study is to evaluate the equilibrium with dedicated equipment as NEUROCOM systems (force-platform based) in order to have an objective assessment of postural control in DS subjects compared to unchallenged age-matched subjects.

Five young Down syndrome subjects, aged 8 to 15 years, and five normal age-matched subjects were included in the study. Static equilibrium was evaluated by Smart Balance (NEUROCOM) system. Subjects have to maintain upright position as steady as they can for 20 seconds on the stabilised force-plate in two conditions – eyes closed and eyes open. The posturograph has a 45cm x 45cm force-platform which evaluates in real time the anterior and posterior displacement of the centre of gravity (COG) during 20-second stance. Feet are placed by the operator on specific landmarks, depending on subject's height. Comparison with normative data is available, since the system has normal database results from age 3.

Three tests were performed for each subject included in the study – Sensory Organisation test (SOT), Limits of Stability (LOS) test and Rhythmic Weight Shift test. We chose these two tests since SOT offers information regarding ability of the subjects to maintain upright position, an essential prerequisite of normal balance. This is a method of quantitative evaluation of the individual's ability to process different sensory cues in order to maintain balance. LOS test reveals and quantifies reductions in the limits of normal sway of the subject during daily movements.

SOT test requires the subject to stand still for 20 seconds in different conditions (1 to 6; for this study, only conditions 1 and 2 were compared between Down syndrome subjects and unchallenged ones-fixed platform, eyes open and eyes closed, respectively). These specific conditions require different sensory inputs to be active in order to maintain stance and by progressively isolating each sensory system we can evaluate the individual's use of each sensory system for balance control.

Besides this Sensory Organisation test (SOT) results in graphical and numerical system, NEUROCOM equipment offers Raw Data analysis which represents time and frequency domain analysis of the centre of pressure movements of the tested subjects – amplitude, frequency, direction and regularity of patient's sway by measuring the action forces.

All subjects were evaluated with two more tests – Limits of Stability (LOS) and Rhythmic Weight Shift. During the last two tests, subjects had to follow as soon as possible, by means of their voluntary control, the own COG movement of a moving target. Both target and COG projection are shown on a display placed in front of subject's eyes.

3. Results

For SOT, each condition was tested twice to evaluate the ability of learning in order to obtain better balance. Individual scores were compared with normal values for each subject. Intergroup comparison was performed for equilibrium scores in the two conditions tested – stable platform with eyes open and closed. SOT scores were normal for all subjects included in the study, with or without Down Syndrome, from graphic and numeric point of view (Fig. 1, condition 1 and 2) (table 1), but Raw Data

analysis showed important differences in the amplitude and frequency of the oscillations of the COG during 20 seconds stance both with eyes open (EO) or eyes closed (EC) (Fig. 2).

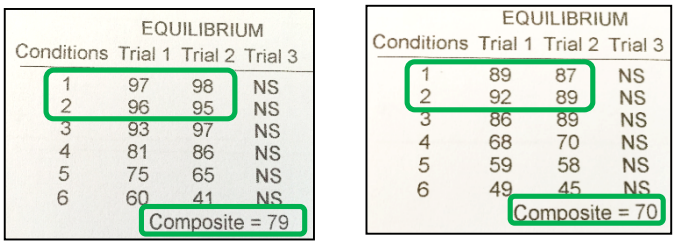

Fig. 1. SOT results in a DS subject and an unchallenged subject (example) - normal results, but lower results in DS subjects (left) for conditions 1, 2 and for composite score

Table 1. Equilibrium scores obtained for each trial in DS subjects and unchallenged subjects

Subject	Condition	Down syndrome subjects		Unchallenged subjects		Normal values
		Trial 1	*Trial 2*	*Trial 1*	*Trial 2*	*Condition*
1	1	93	95	95	96	80.4-86.6%
	2	93	93	93	95	71.6-85.7%
2	1	88	88	97	98	80.4-86.6%
	2	87	89	96	95	71.6-85.7%
3	1	89	87	95	97	80.4-86.6%
	2	89	92	94	95	71.6-85.7%
4	1	85	83	97	97	80.4-86.6%
	2	85	82	95	95	71.6-85.7%
5	1	93	95	94	96	80.4-86.6%
	2	93	90	93	95	71.6-85.7%

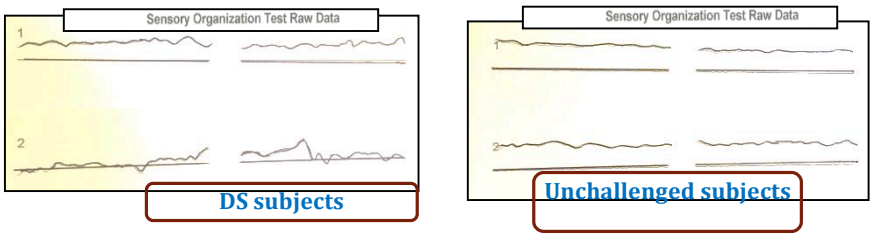

Fig. 2. Raw Data results in a DS subject and an unchallenged subject (example)

SOT Raw Data report shows both the anterior and posterior displacement of the COG and shear forces traces generated during each trial. Type and frequency of sway pattern is useful in evaluating individual way of balancing. The lighter line represents the patient's sway direction and amplitude (anterior = up, posterior = down). H = the heavier line represents the horizontal shear forces produced at the feet level.

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The numeric data report provides the absolute values for each trial. They are used for comparison with normative value range, for research and monitoring patient's evolution under recommended treatment.

COG is placed approximately at half of subject's height, around umbo. Good balance is equivalent with normal mobility while balancing, expressed as COG oscillations in a cone shape, top down during quiet stance. Oscillations in this region of stability are as large as 12.5 degrees in anterior-posterior direction and 16 degrees in lateral direction, and are considered as normal LOS values.

Two parameters were taken into consideration when comparing DS and normal subjects – reaction time (RT) and Directional Control (DCL).

RT represents the time interval between movement of the target and voluntary movement of the COG by the tested subject. If all of the subject's movement is directly toward the target or the intended direction (a straight line), then the amount of extraneous movement would equal zero, and the perfect directional control score is 100%.

For LOS test, most of the DS subjects could not perform the test in all directions (reaction time could not be measured), and when they could perform the test, poor direction control was demonstrated (Table 2).

Table 2. LOS in Down syndrome subjects

Reaction Time (RT) (sec); (NS – not tested; patient was unable to perform the task); good results is to have scores below the normal value (better reaction time)

	Forward		Back		Right		Left		Composite	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Normal values	0.62	0.20	0.45	0.17	0.68	0.23	0.70	0.25	0.51	0.17
Subject 1	0.75		0.86		0.9		NS		NS	
Subject 2	0.91		0.74		0.72		0.62		0.75	
Subject 3	1.11		NS		NS		0.88		NS	
Subject 4	NS		NS		0.85		NS		NS	
Subject 5	0.77		0.89		0.66		1		0.83	

Directional Control (DCL) (% straight line path); (good results = scores greater than normal value; better accuracy of the trajectory of voluntary movement)

	Forward		Back		Right		Left		Composite	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Normal values	84.6	7.7	45.9	17.0	78.5	8.7	80.9	8.7	72.6	7.6
Subject 1	36		2		53		NS		NS	
Subject 2	22		48		57		69		49	
Subject 3	70		NS		NS		60		NS	
Subject 4	NS		NS		75		NS		NS	
Subject 5	80		67		75		77		75	

For Rhythmic Weight Shift test performed both laterally and in the anterior-posterior direction at three specific velocities (slow, moderate and fast), DS subjects showed poor control direction as well as accuracy, compared with normal values (Table 3).

Table 3. Rhythmic Weight Shift in Down syndrome subjects

	On-Axis Velocity for left/right direction				Directional Control (DCL) for left/right direction (% straight line path)			
	Slow	Moderate	Fast	Composite	Slow	Moderate	Fast	Composite
Normal values	2.1	3.3	6.2	4	80	82	85	81
Subject 1	2.6	3.5	7.5	4.5	72	80	89	80
Subject 2	3.8	4.3	7.7	5.3	69	80	89	79
Subject 3	2.6	3.1	4.2	3.3	64	75	73	71
Subject 4	3	5.1	10.9	6.3	72	78	91	80
Subject 5	2.5	3	7.2	4.2	50	73	75	66
	On-Axis Velocity for front/back direction				Directional Control (DCL) for front/back direction (% straight line path)			
	Slow	Moderate	Fast	Composite	Slow	Moderate	Fast	Composite
Normal values	1.5	2	4	3	75	79	81	78
Subject 1	0.8	1.1	0.9	0.9	26	45	60	44
Subject 2	2.4	2.8	4.8	3.3	58	74	74	69
Subject 3	1	1.4	0.8	1.1	52	66	20	46
Subject 4	1.6	2.8	3.8	2.7	64	74	73	70
Subject 5	1.8	4	2.4	2.7	53	78	46	59

Analysis of the postural control revealed a lower performance in maintaining the upright position from time domain point of view in Down syndrome group, as well as a low reaction time and voluntary direction control in DS subjects compared to unchallenged ones.

4. Discussions and conclusions

Evaluation of equilibrium is based on evaluating independently the three sensory systems involved in balance (somatosensory, visual and vestibular ones) and also to evaluate their congruency and central integration.

The vestibular system is one of the first sensory systems that develop prenatally (Shumway-Cook, 1992), but it takes the newborn one year to learn to use this information. Learning process is highly correlated with experience – more motor activity the child has, faster and better development of vestibular function is obtained.

For DS children, hypomobility and lack of cerebellum function impedes upon motor experience and this will delay vestibular system's normal functioning.

Since the subjects included in the study are more than 12 years old, we focused in our postural control evaluation on the third chronological type of postural reactions – equilibrium.

SOT scores evaluate the equilibrium score for each trial by comparing the angular difference between the patient's maximum COG displacements, from anterior to posterior with theoretical maximum displacement (12.5 degrees). The result is expressed as an inverse percentage between 0 and 100, with scores approaching 0 that indicate sway amplitude closely to limits of stability (risk of falling), and 100 value indicating perfect stability. The software is based on comparison between subject's scores and normal values for different age groups, starting from age 3.

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As already demonstrated (Shumway-Cook, 1985), children with DS have a higher than normal latency in initiating and executing goal-directed movements. Time needed for executing high accuracy movements, but also for standing and walking is also longer than unchallenged peers. Sensorimotor deficits present in DS children also include perceptual-motor slowness (Elliott & Bunn, 2004: 137), limb control problems and impaired motor efficiency (Wuang et al., 2000). LOS test and rhythmic weight shift scores showed similar abnormal results compared with normal values (Table 3), with increased reaction time and non-straight direction of voluntary displacement of the COG when trying to follow the target.

Postural control in DS children is important and affects daily activities: disequilibrium, late walking age (3-4 years), enlarged base of standing, falling easiness when running, difficulty and fear in going downstairs, difficulty and fear in biking learning and difficulty to stop support wheels, fear or even panic while standing alone on an oscillating surface (Haley, 1986, 1987). This latter problem seems to be specific to DS children, as opposed to other mental retardation subjects.

Troubles in balance are common to DS children, but the impact varies from child to child. Felicioli and Moretti (1984) found a varying percentage (41.4 to 48.9%) of disequilibrium in their small number casuistry. They think that the smaller percentage, as related on subject persons born a five-year period later, is already the result of a wider and earlier neuro-psychomotor rehabilitation intervention. This is the method of choice that should be available for DS newborn-sensory integrative intervention, vestibular stimulation, neurodevelopmental therapy are effective methods to be used in children with an intellectual disability (Harris, 1981; Henderson, 1981).

SOT evaluation, mainly of the shear force ratio, demonstrates abnormal sway pattern in DS subjects compared to age-matched unchallenged subjects. More than that, we could demonstrate by LOS test and Rhythmic Weight Shift evaluation pathological differences in time reaction and directional voluntary control in DS subjects when asking them to perform a motor task. Perception difficulties are common in Down syndrome subjects and explain their standing and walking difficulties – higher postural sway velocity during standing and broad base of support during walking, fear of going down or up the stairs without bar support or another person.

Motor control problems are present in Down syndrome children since birth (hypotonia, low joint stability and joint hypermobility) and impede upon both development of motor control and vestibular system function development if early rehabilitation is not provided. This characteristic lasts for the whole life of the DS person. It is essential that therapeutic programs based on the stimulation of postural reactions to be utilized in the intervention program.

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