European Review for Medical and Pharmacological Sciences 2015; 19: 201-208

Independent reaching of the sitting position depends on the motor performance in the 3rd month of life

E. GAJEWSKA[1], M. SOBIESKA[1], J. MOCZKO[2], A. KUKLIŃSKA[1], I. LAUDAŃSKA-KRZEMIŃSKA[3], W. OSIŃSKI[3]

[1]Department of Rheumatology and Rehabilitation, Poznań University of Medical Sciences, Poznań, Poland
[2]Department of Computer Science and Statistics, Poznań University of Medical Sciences, Poznań, Poland
[3]Departament of Studies on Physical Activity and Health Promotion, University School of Physical Education in Poznań, Poznań, Poland

Abstract. – OBJECTIVE: Sitting is one of milestones in motor development. However, reaching of the sitting position must precede achieving the ability of independent sitting. Qualitative assessment of motor performance at 3 months of age, with the prospective quantitative assessment of the function of independent reaching of the sitting position at the age of 8 months.

PATIENTS AND METHODS: 125 children, 51 girls and 74 boys (born at term n = 78; born prematurely n = 47) were subject to prospective assessment of motor development with qualitative characteristics at the age of 3 months and quantitative characteristics at the age of 8 months. In parallel, the children were subjected to neurological assessment. Risk factors that could potentially affect motor development were analyzed.

RESULTS: Children who at the age of 3 months performed at least 13 /15 qualitative elements in the prone position and at least 13/15 qualitative elements in the supine position, at the age of 8 months reached independently the sitting position. Poor qualitative assessment at the age of 3 months and a higher prevalence of risk factors increased the risk of non-reaching the sitting position. In the prone position, the pelvis, lower limbs, the arms and shoulders showed the most expressed differences between the children who reached or did not reached the independent sitting. For the supine position, the pelvis and lower limbs, as well as the extension of the spine and correct alignment of the shoulders showed the most expressed differences.

CONCLUSIONS: Proper qualitative development at the age of 3 months is a good predictor of the achievement of independent reaching of the sitting position at the age of 8 months.

Key Words:
Quality assessment, Motor performance, Sitting position.

Introduction

The first signs of upright control appear in the third month of life and these are the correct upright head control along with isolated movements of the head[1]. In contrast, trunk control develops in the following months from the fourth to the sixth month of life[2], so that an infant at the age of 8 months can achieve the function of reaching the sitting position, which is performed from the position on all fours; and maintain the sitting position. Sitting is often one of the elements in the diagnosis used in medical practice or physiotherapy, it is an element of development scales, also referred to as a milestone in the motor development of a child[3-7].

Earlier studies analyzing the function of sitting in infants have, thus, far been focused on checking: development of muscle synergies for balance reactive responses to external perturbations[8-12], development of muscle synergies for anticipatory balance during learning to reach[13-15] and the development of ground reaction forces that stabilize the center of mass over the base of support[16,17]. None of these methods have allowed evaluation of, or offered control for, variable contributions of different trunk segments to postural control and none have addressed the question of how infants acquire the vertical sitting position.

Among the few authors who investigated the subject of how children reach the sitting position,

Corresponding Author: Ewa Gajewska, MD; e-mail: ewagajewska1011@gmail.com

analyzing how postural control changes over time (between 3 and 8 months of age) in sitting balance in the course of normal development, were Saavedra and van Donkelaar[18]. For this purpose they used electromyography (EMG) measurements, kinematics and video recordings of changes in muscle activity in the subsequent months of life during 3 minutes of supported sitting.

However, none of these studies have shown which elements of early motor development are essential for a child to achieve the function of reaching the correct sitting position. From the point of view of functional development, the imposed sitting position described in the above publications is different than the ability to reach the sitting position independently and to maintain the sitting position. Some authors[3,6,7] suggest that what can be treated as an independent activity is only reaching the sitting position from the crawl position and maintaining independent sitting. In a child developing properly, these steps follow one after another in a smooth, genetically encoded manner. Most authors[3-5,9] agree that children are able to sit independently in the 8th month of life. Therefore, on the basis of earlier research, presenting a self designed "Quantitative and qualitative assessment sheet"[6,7,19] a hypothesis was put forward that motor development at the age of 8 months, i.e. independent reaching of the sitting position, reflects motor behavior of children at the age of 3 months, observed in prone and supine positions.

The study poses, thus, the following research questions: Is the proper qualitative development at the age of 3 months a good predictor of reaching the sitting position and sitting independently? Is the assessment of the motor development conducted in prone position a better predictor than assessment conducted in supine position? What elements of qualitative assessment in the 3rd month of life are the predictors of the function of independent reaching of the sitting position in 8th month of life? The purpose of the study is qualitative assessment of motor performance at the age of 3 months in prone and supine positions with prospective quantitative assessment of motor performance in the 8th month of life (independent reaching of the sitting position).

Patients and Methods

An experienced physiotherapist conducted a prospective examination of motor development in children at the age of 3 and 8 months, following the methodology described previously[6,7]. In parallel, the assessment of the development of all children in the 3rd and 8th month of life was performed by a neurologist, according to the examination scheme described earlier[7]. Exact description is given in Procedure section. The neurologist provided information on the level of motor development achieved by children in the 8th month of life, and in case of children in whom cerebral palsy (CP) was suspected at the age of 8 months, final diagnosis was made at 18 months, following the Polish rules. Eventually, 125 children, 51 girls and 74 boys, for whom all data were complete, with no genetic or metabolic disorders or severe birth defects were qualified for the participation in the study. There were 78 infants born at term and 47 born prematurely. In case of prematurely born infants, their corrected age was taken into consideration[20]. On average children in the investigated group were born at week 37±4, the mean body weight was 2889±946 g, the mean head circumference was 33±2 cm, the mean body length was 53±5 cm, the mean chest circumference was 32±3 cm.

The Apgar scale scoring was as follows: at 1th minute: median 10 (lower quartile Q25=8, upper quartile Q75=10), at minute 3th, 5th and 10th the score was 10 points (quartiles 9 to 10). Risk factors that could potentially affect motor development were analyzed: intraventricular hemorrhage (IVH), the presence of respiratory distress syndrome (RDS), intrauterine hypotrophy, hyperbilirubinemia based on medical records, after consulting a neurologist. A division with respect to the Apgar score was not taken into account, as in the 5th minute all children already achieved a good assessment.

Children were not divided according to sex, as none of the previous studies[6,7,19] showed any differences between girls and boys.

In case of children with suspected IVH, USG was performed immediately after birth and control assessment was routinely performed at 3 months. In all other investigated children, for comparison, the USG was also performed at 3 months, even if no risk factors were described in medical history. The examination was performed at the clinic of the Wielkopolska Center for Child and Adolescent Neurology in Poznan (Poland) and the child clinic in Bydgoszcz (Poland) in the years 2011-2013.

Informed consent was obtained from all of the subjects and the study was approved by the Research Ethics Committee of Poznan University of

Medical Sciences and registered under no. 22/10 (07-01-2010). It conformed to all ethical issues included in the Helsinki Declaration.

Procedure

Neurological Assessment

A neurologist assessed all children at 3rd month, basing on the Denver Development Screening Test II (DDST II)[21,22] and the assessment of the reflexes, hypotonia/hypertonia, and symmetry, as suggested by Touven[23]. After conducting the examination neurologists classified a child into one of three groups: normal (no neurological abnormalities), suspected (not requiring rehabilitation – for observation) and abnormal. A child was classified as abnormal if it exhibited clear neurological disorders, such as increased (hypertony) or decreased (hypotony) muscle tone accompanied by abnormal reflexes and failure to perform tasks in the area of motor skills for a given age group in the DDST II test. A child was classified into the suspected group – not requiring rehabilitation – for observation if it exhibited mild symptoms of neurological disorders, such as mild muscle tone regulation disorders, slight reflex dysfunction, minor developmental asymmetry and a delay in the area of motor skills in the DDTS II test. Two neurologists with 20 years of clinical experience took part in the project. In the 8th month, a neurologists assessed children again and ascribe them to the maximum reached motor performance level (expressed as month) and pointed at children suspected for cerebral palsy. In their case, final diagnosis was confirmed at the age of 18 months, according to literature[24].

The Functional Assessment

A physiotherapist assessed the motor performance of each child, in the 3rd month of life, according to the previously described "Quantitative and qualitative assessment sheet"[6,7,19]; only the qualitative assessment results were analyzed. The qualitative assessment in the 3rd month of life included 15 elements in the prone position and 15 elements in the supine position. In the prone position the assessment involved: isolated head rotation, arm in front, forearm in intermediate position, elbow outside of the line of the shoulder, palm loosely open, thumb outside, spinal cord segmentally in extension, scapula situated in medial position, pelvis in intermediate position, lower limbs situated loosely on the substrate, foot in intermediate position. In supine position the assessment involved: head symmetry, spinal cord in extension, shoulder in balance between external and internal rotation, wrist in intermediate position, thumb outside, palm in intermediate position, pelvis extended, lower limb situated in moderate external rotation and lower limb bent at a right angle at hip and knee joints, foot in intermediate position – lifting above the substrate. For symmetrical parts of the body, both sides were assessed to exclude asymmetry.

Each element was assessed as 0 – test performed only partially or completely incorrectly, 1 – test performed completely correctly. The duration of the examination performed by the physiotherapist was between 10 and 15 minutes. Each assessed element had to be observed at least three to four times during the test. Maximum of 15 points could be given for prone position and maximum 15 points for the supine position, as well. In the 8th month only the function of independent reaching of the sitting position was assessed. According to the results of this assessment children were next divided for the analysis of the characteristics from the 3rd month of life.

The neurological examination was performed independently of the physiotherapeutic assessment, both the neurologist and the physiotherapist had information only about whether an infant was born prematurely or at term in order to calculate the corrected age, but they were not aware of the infant's clinical history details nor the parallel opinion.

Statistical Analysis

Due to the nature of the variables the results were presented as medians with quartiles (Q25-Q75), and they were analyzed with non-parametric tests. Comparisons between the two groups for the total variables (sum of quality in prone position, sum of quality in supine position) were made using the U test Mann-Whitney test. The assumed statistical significance level was at least $p < 0.05$. For dichotomous variables (all quality elements in prone and supine positions), on the other hand, comparisons were made using the Pearson's Chi^2 test with Yates' correction and the Chi^2 test value was given (at least $p < 0.05$).

Results

The whole investigated group was divided according to the final developmental level reached

in the 8th month of life (neurologic assessment). In parallel, independent reaching of the sitting position was assessed by a physiotherapist. For the subgroups revealed that way the qualitative characteristics of the 3rd month, in prone and supine positions were calculated, and the number of children positive for evaluated risk factors was checked. All the data are given in the Table I.

All children who at the age of 3 months performed at least 13/15 qualitative elements in the prone position, and at least 13/15 qualitative elements in the supine position developed normally and at the age of 8 months performed independent reaching of the sitting position. It is worth depicting, however, that neurologist classified only 36 from 73 of these children as normal (developed properly).

Given the poor qualitative assessment at the age of 3 months and more frequent incidence of risk factors such as prematurity, IVH, RDS, intrauterine hypotrophy, hiperbilirubinemia, the assessment at the age of 8 months was worse. These children failed to achieve the function of reaching the sitting position independently, their development was slightly delayed or one could suspect cerebral palsy (CP), and this diagnosis was confirmed by a neurologist at the age of 18 months. Along with worsening motor performance, also the neurological assessment was worse.

Considering the qualitative characteristics analyzed in the prone position at the age of 3 months, one may observe that the position of the pelvis and lower limbs (lower limbs loosely situated on the substrate) and the arms and shoulders showed the most expressed differences between the children who reached or did not reached the function of independent reaching of the sitting position (Table II).

The positioning of the pelvis and lower limbs, as well as the extension of the spine and correct alignment of the shoulders at the age of 3 months showed the most expressed difference between the children who reached or did not reach the function of independent reaching of the sitting position (Table III).

Discussion

The main research question posed in this paper was whether one can predict the achievement of the ability to reach the independent sitting position at the age of 8 months on the basis of the qualitative assessment of elements of the motor performance at the age of 3 months. It seems well documented that if a 3-month-old child was highly assessed in both prone and supine position, the probability of achieving independent reaching of the sitting position in the 8th month ability is also high, and inversely. When addressing a question which elements of motor performance are essential for the development at the age of 8 months to be complete, the crucial elements mainly include the axis of the body: the correct curvature of the spine, the alignment of the shoulders in an intermediate position and the adoption of the intermediate position by the pelvis. This has already been shown in previous publications on motor development[6,7,19], which were based on similar theoretical assumptions.

Publications on the sitting function available in the literature[8-18] focus on the analysis of sitting rather than on the function of independent reaching of the sitting position, even if a child is placed in this position by the caregiver. This approach allows for a biomechanical analysis of the muscles that are needed to perform this function, but it does not answer the question as to what determines independent reaching of this function. From the point of view of the rehabilitation process it is important, however, to find out what the reason for not achieving this function is and whether a therapy can affect this process. It is for this reason that a qualitative assessment of the motor function is essential so that the effects of therapy could be demonstrated. Moreover, if apart from the overall assessment (function performed/not performed) we examine in detail which elements of movement or posture are disturbed, it is easier to point to the main objective of a therapy, and it is easier to evaluate, whether the applied procedure brings results.

If we analyze carefully the characteristics differentiating children assessed at the age of 3 months of age, who either reached or failed to reach the sitting position at the age of 8 months, the elements analyzed in the prone position seem more important, especially the positioning of the pelvis and lower limbs, arms and shoulders. This probably has to do with overcoming gravity, which was also highlighted by other authors[18]. Similarly, as described in previous publications[6] the manifestation of correct motor elements, referred to as proximal characteristics, determines the acquisition of higher motor skills, such as independent reaching of the sitting position.

Table I. The course of motor development for the entire group (n = 125) and the number of risk factors.

3rd month, qualitative assessment in prone position (max = 15); supine position (max = 15)	Neurological assessment in 3rd month normal/ suspected/abnormal	Prematurity	IVH grade	RDS	Hypotrophy	Hyperbilirubinemia	Physiotherapeutic assessment at the age of 8 months	The level of motor development achieved at the age of 8 months (neurological assessment)
13 (7-15)								
13 (7-15)	36/12/25	23	I -2 II -- III-1	6	1	12	Reaches the sitting position, n = 73	8 months n = 73
0 (0-1)								
2 (0-15)	3/0/11	3	I-1 II-2 III--	0	2	3	Fails to reach the sitting position, n = 52	7, n = 14
2 (0-6)								
5 (0-9)	0/6/16	11	I-3 II-2 III-1	5	2	4		6, n = 22
6 (1-8)								
6 (2-10)	0/3/5	4	I-2 II-1 III--	1	2	2		5, n = 8
9; 7	0/0/1	1	--	0	0	0		3, n = 1
0 (0-2)								
0 (0-0)	0/0/7	5	I-- II-1 III-2	3	1	1		Suspected CP, n = 7

Table II. A comparison of the assessment of qualitative characteristics typical for the age of 3 months in the prone position, due to the achievement of the ability to reach independent sitting position at the age of 8 months (reaches the sitting position, n = 73/ fails to reach the sitting position, n = 52), using the Chi^2 Pearson test with Yates' correction. Chi^2 and p values were given. The most important differences are shown in bold.

Qualitative characteristics in the prone position	Side of the body	Chi^2 values	*p* value
Isolated head rotation		16.80	0.00004
Arm in front, forearm in intermediate position, elbow outside of the line of the shoulder	Right	17.99	0.00002
	Left	**28.90**	0.00000
Palm loosely open	Right	16.82	0.00004
	Left	20.04	0.00001
Thumb outside	Right	19.68	0.00001
	Left	23.21	0.00000
Spinal cord segmentally in extension		21.15	0.00000
Scapula situated in medial position	Right	**26.15**	0.00000
	Left	**31.80**	0.00000
Pelvis in intermediate position		**25.34**	0.00000
Lower limbs situated loosely on the substrate	Right	**32.61**	0.00000
	Left	**30.78**	0.00000
Foot in intermediate position	Right	14.62	0.00013
	Left	17.79	0.00002

Table III. A comparison of the assessment of qualitative characteristics typical for the age of 3 months in the supine position, due to the achievement of the ability to reach independent sitting position at the age of 8 months (reaches the sitting position, n = 73/ fails to reach the sitting position, n = 52), using the Chi^2 Pearson test with Yates' correction. Chi^2 and *p* values were given. The most important differences are shown in bold.

Qualitative characteristics in supine position	Side of the body	Chi^2 values	*p* value
Head symmetry		13.84	0.00020
Spinal cord in extension		**17.99**	0.00002
Shoulder in balance between external and internal rotation	Right	**16.80**	0.00004
	Left	**23.37**	0.00000
Wrist in intermediate position	Right	16.20	0.00006
	Left	19.57	0.00001
Thumb outside	Right	14.71	0.00013
	Left	10.82	0.00100
Palm in intermediate position	Right	13.20	0.00028
	Left	14.71	0.00013
Pelvis extended (no anteversion, no retroversion)		**18.53**	0.00002
Lower limb situated in moderate external rotation	Right	**23.22**	0.00000
	Left	**20.27**	0.00001
Lower limb bent at a right angle at hip and knee joints, foot in intermediate position – lifting above the substrate	Right	**23.39**	0.00000
	Left	**22.18**	0.00000

Out of 33 children born prematurely, but not burdened with risk factors, 21 achieved the function of independent reaching of the sitting position at the age of 8 months. Among 47 children born prematurely and burdened with risk factors, 14 had IVH, and of these 9 were diagnosed with RDS; only a few achieved the function of independent reaching of the sitting position at the age of 8 months (two children out of six diagnosed with I IVH; 0/6 with II IVH and

0/2 with III IVH). Children who at the age of 3 months fail to manifest the elements of correct motor performance and who are burdened with risk factors: intraventricular haemorrhage, respiratory distress syndrome, hypotrophy or hyperbilirubinemia, especially those born prematurely, should be considered at risk of delayed motor development, and even cerebral palsy. They should be subject to careful observation and treatment from the earliest months of life. Owing to this research the assessment of a child motor performance carried out as early as at the age of 3 months may indicate abnormalities, which can be corrected by means of properly planned rehabilitation.

The main idea to perform qualitative assessment of the motor performance is to establish a tool that allows to predict further motor development and to plan exactly the therapy in case of children with motor deficits. It seems quite important that assessment made by neurologist, though pointed at children with lower performance, was not predictive for the reaching of the desired function. Qualitative assessment provided a much more clear cut-off criterion than the general neurological assessment.

The suggested "Quantitative and qualitative assessment sheet" seem to be a reliable tool to predict motor performance of any child. Perhaps, it could be even narrowed to the proximal elements, assessed in prone and supine positions respectively at the age of 3 months, for the prognosis of motor development in the subsequent months of life, to make it a more transparent and accessible tool for different professionals and even parents (as the basis for screening). Further researches are necessary to clarify this question.

Conclusions

It seems that correct qualitative development at the age of 3 months is a good predictor of independent reaching of the sitting position at the age of 8 months.

The elements observed in the prone position at 3rd month seem to be a better predictor of further motor development than those in supine position.

The most important qualitative characteristics typical for the age of 3 months that determine the performance of independent reaching of the sitting position are: the intermediate positioning of the pelvis and the correct alignment of the shoulder girdle (proximal characteristics).

Acknowledgements

The study was conducted under a research grant of the Ministry of Science and Higher Education in Poland KBN N N404269639.

Conflict of Interest

The Authors declare that they have no conflict of interests.

References

1) Assaiante C, Amblard B. Ontogeny of head stabilization in space during locomotion in children- influence of visual cues. Exp Brain Res 1993; 93: 499-515.
2) Shumway-Cook A, Woollacott MH. Development of postural control. In: Motor Control: Translating Research into Clinical Practice (3rd ed.). Philadelphia, PA: Lippincott, Williams & Wilkins, 2007.
3) Vojta V, Peters A. The Vojta Principle. Springer-Verlag, 2007.
4) Gajewska E. Diagnostic instruments for assessing early motor development in child physiotherapy. Neurologia Dzieci ca 2011; 20: 53-58 [in Polish].
5) Hadders-Algra M. Variation and variability: key words in human motor development. Phys Ther 2010; 90: 1823-1837.
6) Gajewska E, Sobieska M, Moczko J. Qualitative motor assessment allows to predict the degree of motor disturbances. Eur Rev Med Pharmacol Sci 2014; 18: 2507-2517.
7) Gajewska E, Sobieska M, Kaczmarek E, Suwalska A, Steinborn S. Achieving motor development milestones at the age of three months may determine, but does not guarantee, proper further development. Sci World J 2013; 2013: 354218.
8) Bertenthal BI, Rose JL, Bai DL. Perception-action coupling in the development of visual control of posture. J Exp Psychol Hum Percept Perform 1997; 23: 1631-1643.
9) Hadders-Algra M, Brogren E, Forssberg H. Ontongeny of postural adjustments during sitting in infancy: variation, selection and modulation. J Physiol 1996; 493: 273-288.
10) Harbourne RT. A kinematic and electromyographical analysis of the development of sitting posture in infants. Dev Psychobiol 1993; 26: 51-64.
11) Hedberg A, Carlberg EB, Forssberg H, Hadders-Algra M. Development of postural adjustments in sitting position during the first half year of life. Dev Med Child Neurol 2005; 47: 312-320.
12) Hirschfeld H, Forssberg H. Epigenetic development of postural responses for sitting during infancy. Exp Brain Res 1994; 97: 528-540.
13) Thelen E, Spencer JP. Postural control during reaching in young infants: a dynamic systems approach. Neurosci Biobehav Rev 1998; 22: 507-

514.

14) van der Fits IBM, Klip AW, van Eykern LA, Hadders-Algra M. Postural adjustments during spontaneous and goal-directed arm movements in the first half year of life. Behav Brain Res 1999; 106: 75-90.

15) Witherington DC, von Hofsten C, Rosander K, Robinette A, Woollacott MH, Bertenthal BI. The development of anticipatory adjustments in infancy. Infancy 2002; 3: 495-517.

16) Cignetti F, Kyvelidou A, Harbourne RT, Stergiou N. Anterior-posterior and medial-lateral control of sway in infants during sitting acquisition does not become adult-like. Gait Posture 2011; 33: 88-92.

17) Harbourne RT, Stergiou N. Nonlinear analysis of the development of sitting postural control. Dev Psychobiol 2003; 42: 368-377.

18) Saavedra SL1, van Donkelaar P, Woollacott MHJ. Learning about gravity: segmental assessment of upright control as infants develop independent sitting. Neurophysiology 2012; 108: 2215-2229.

19) Gajewska E, Bara ska E, Sobieska M, Moczko J. Motor performance in the third, not the second month, predicts further motor development. J Mot Behav 2014 Nov 21: 1-10. [Epub ahead of print].

20) Restiffe AP, Gherpelli JL. Comparison of chronological and corrected ages in the gross motor assessment of low-risk preterm infants during the first year of life. Arq Neuropsiquiatr 2006; 64: 418-425.

21) Ślenzak J, Michałowicz R. Test Denver orientacyjny test psychoruchowego rozwoju dziecka [in Polish]. Problemy Medycyny Wieku Rozwojowego 1973; 3: 47-76.

22) Drachler M de L, Marshall T, de Carvalho Leite JC. A continuous-scale measure of child development for population-based epidemiological surveys: a preliminary study using Item Response Theory for the Denver Test. Paediatr Perinat Epidemiol 2007; 21: 138-153.

23) Touwen BCL. Neurological Development in Infancy. Clinics in Developmental Medicine No. 58. Philadelphia: Lippincott, 1976.

24) Smithers-Sheedy H, Badawi N, Blair E, Cans C, Himmelmann K, Krägeloh- Mann I, McIntyre S, Slee J, Uldall P, Watson L, Wilson M. What constitutes cerebral palsy in the twenty-first century? Dev Med Child Neurol 2014; 56: 323-328.