

The development of postural control in 6–17 old years healthy children. Part I Postural control evaluation in modified Clinical Test for The Sensory Interaction on Balance in 6–17 old year children (mctsib)

Authors' Contribution:

A – Study Design
B – Data Collection
C – Statistical Analysis
D – Data Interpretation
E – Manuscript Preparation
F – Literature Search
G – Funds Collection

Krystyna Orendorz-Frączkowska^{ABCDEF}, Marzena Kubacka^{EF}

Chair and Clinic of Otolaryngology, Head and Neck Surgery, Medical University of Wrocław, Wrocław, Poland;
Head of Clinic: Prof. Krzysztof Morawski MD PhD

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ABSTRACT:

Introduction: Proper development of postural control in children is connected with the maturation of the central nervous system, development of sensory organisation with appropriate use of proprioceptive, visual, vestibular information as well as reactions and postural strategy which allow the maintenance of balance in changeable environmental conditions. Developmental disturbances in this particular area is reflected in postural dysfunctions and the assessment of these dysfunctions and disturbances needs referring to normative values of the healthy population of children.

Aim: Examination of postural control development in children aged 6–17 years.

Material: 127 healthy children were tested (65 girls and 62 boys) aged 6–17 years.

Method: Laryngological investigation, medical history interview, audiometry and tympanometry were conducted in all children. In the evaluation of postural control (mCTSIB-modified Clinical Test For The Sensory Interaction On Balance) a computer posturography system was used (Balance Master Neurocom).

Results: Further development of postural control was found in healthy children up to the age of 13 years of age. The development was not linear but showed transient characteristics with a faster development stage between the age of 6–7 and 8–9. Better postural control in girls, particularly the youngest, in comparison with boys was noticed.

Conclusions: 1. The values of norm postural control in posturographic test mCTSIB in children aged 6–17 was established. In this test postural control development was completed in children before 13 year and it was not linear. 2. Due to gender differences it seems appropriate to use separate norms in order to evaluate the development of postural control in boys and girls.

KEYWORDS:

balance maturation, balance system in children, posturography, static and dynamic balance, vestibulospinal reflexes

INTRODUCTION

The ability to maintain an upright position of the body and maintain balance during movements develops as a result of a complex process occurring in the first years of a child's life. The process is preceded by mastering subsequent functions based on reflexes, ultimately leading to obtaining an upright body position [1–3, 6–13, 14, 18–26, 28–36].

Postural control is an important indicator of the child's proper development because it is closely related to the process of maturation of the central nervous system, with the harmonious development of sensory organisation, reactions and postural strategies, motor development of the child and cognitive and social functions [2, 3, 6, 7, 9, 10, 12–14, 19, 21, 23, 25, 29, 32, 33].

Developmental disorders in this area are reflected in later postural dysfunctions [11]. An objective posturographic, repeatable assessment of the efficiency of the balance system can constitute an important element of the oto-neurological examination, not only in a child with impaired balance or dizziness, but also displaying developmental deficits.

Due to the process of maturation of the balance system occurring at the developmental age, the normative values of each applied test change, which requires determining the age standards for a healthy paediatric population. The presented work, planned as part of a series, presents, due to the volume of the paper, the results of postural control tests using a modified Romberg test (mCTSIB-modified Clinical Test for The Sensory Interaction on Balance) in healthy children aged 6–17 [27].

PURPOSE OF PAPER

Evaluation of postural control development in Polish children aged 6 to 17 years.

MATERIAL

One hundred twenty-seven otoneurologically healthy children (65 girls and 62 boys) between the ages of 6 to 17 years, in whom known diseases with a potential impact on the hearing organ and organ of balance as a whole were excluded in interview and physical examination. A condition necessary for inclusion in the normal group was proper physical development, healthy organ of movement and vision, normal hearing and function of the ear trumpet, moreover, lack of balance disorders in static testing and dynamic testing (Romberg test and the straight line walking test with eyes open and closed) [30].

METHOD

The subjects were divided into 6 age groups (5 boys and 5 girls in each, with the exception of the youngest group, which comprised 13 children – 6 boys and 7 girls). The age group included children over a certain age who at the same time did not exceed it by more than 6 months. Hearing tests (audiometry tonality, tympanometry, otoacoustic emissions in the youngest) and posturographic examination using the mCTSIB test were carried out in all (simplified version of the sensory organisation test – SOT) in four sensory conditions:

1. Eyes open, firm surface (Firm EO);
2. Eyes closed, firm surface (Firm EC);
3. Eyes open, unstable surface (foam) (Foam EO);
4. Eyes closed, unstable surface (foam) (Foam EC).

The average speed of the centre of gravity (°/s) was recorded from three trials of 10 seconds each. In order to assess the impact of visual control on postural stability, Romberg index was calculated (the ratio of the centre of gravity's tilt speed with eyes closed to the value of this velocity with eyes open) under the conditions of a firm base (Firm). The study used the NeuroCom VSR Basic Balance Master with diagnostic, analysis and training software in version 8.0 VSR [26]. The compliance of the tested variables with the normal distribution was assessed using the Kolmogorov-Smirnov and Chi-square tests. Statistica software was used for statistical analysis. Statistically significant values were assumed as $p < 0.05$.

RESULTS

Characteristics of subjects

With the exception of the youngest group, in which girls were slightly heavier and taller than boys, in parallel age groups, a parallel linear

increase in body mass and height was observed in both sexes; however, in each age group, the boys showed an average higher body weight and were taller. Until the age of 15, gender differences in this area were not significant. Boys aged 16–17 were characterised by a significant increase in weight and body height, which resulted in the lack of such changes in girls, a significant difference for their benefit. The average body weight ranged from 24 kg in 6-year-old children (22 kg in boys, 25 kg in girls) to 61.5 kg in 17-year-olds (74 kg in boys, 58 kg in girls). The height of 6-year-old children was 118 cm (116 in boys, 123 in girls) to 170.5 cm in 17-year-olds (174 cm in boys, 170 cm in girls). The average values of body weight and height in all age groups were between the 50th and 70th percentiles.

Results of mCTSIB test

Fig. 1. presents the results of mCTSIB test under conditions of full access to sensory information (firm EO) and after the exclusion of visual control (firm EC).

In the conditions of inflow of all sensory information (firm EO), the values of mean velocities of the centre of gravity were systematically decreasing with each subsequent age interval, however, they did not display significant differences in children aged 6–13 (groups I–IV), but were significantly higher than in the two oldest groups ($p < 0.005$ and $p < 0.00001$, respectively). No significant differences in postural velocity were found in children aged 14–17 (groups V, VI, $p < 0.09$).

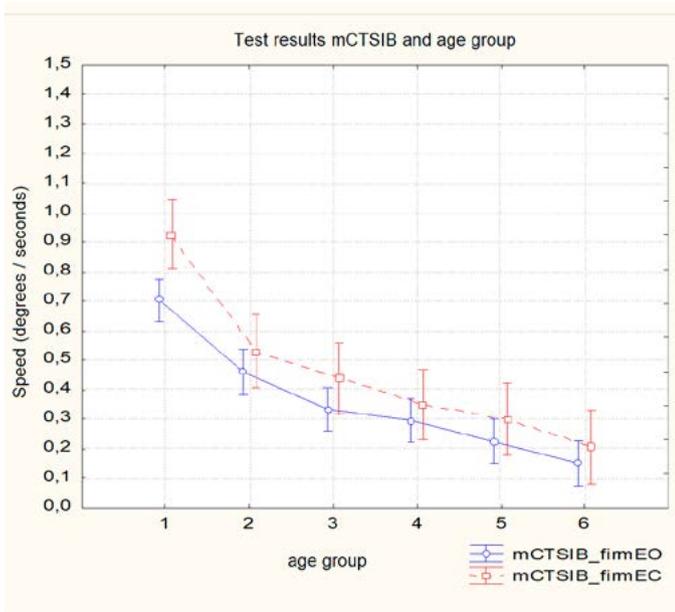
After excluding visual control, postural velocity of the youngest children (group I) was significantly higher than in all other age groups (groups II–VI $p < 0.000000$).

Also, the stability of the subsequent age group (8–9 years) was significantly worse in comparison with the IV–VI group ($p < 0.03$ $p < 0.01$, $p < 0.0003$) and group III (10–11 years, respectively) from group VI ($p < 0.00$).

Fig. 2. illustrates the results of mCTSIB test under restricted access to proprioceptive information with eyes open (foam EO) and with the exclusion of visual control (foam EC).

The restriction of proprioceptive information (foam EO) significantly worsened postural stability in all children, and the exclusion of visual control (EC foam) increased instability to a greater extent than in a stable base condition. The youngest children (group I) displayed a significantly higher mean value of the centre of gravity deviation from each of the other groups of children ($p < 0.000000$). A lowering of the studied parameter was observed up to 17 years of age, but significant differences occurred only up to the age of 13 (including IV group, $p < 0.02$).

After excluding visual inspection (foam EC), significantly higher values of the examined parameter were also found in Group I in comparison with older children ($p < 0.000000$). In each group, a drop in average velocities was observed, but significant differences between successive age ranges occurred in children up to 11 years of age (groups I–III, $p < 0.03$, $p < 0.005$, $p < 0.01$).



Ryc. 1. Summary of the average values of the centre of gravity speed of the body in °/s with eyes open (firm EO) and closed (firm EC) across age groups.

Tab. I. summarises the results of mCTSIB test in all sensory conditions, where significant differences in the velocity of the centre of gravity between the age groups were observed.

The analysis of the values of parameters included in the table demonstrates that after the age of 13, they are not subject to further significant improvement, which allows to assume that the development process in this respect has been completed.

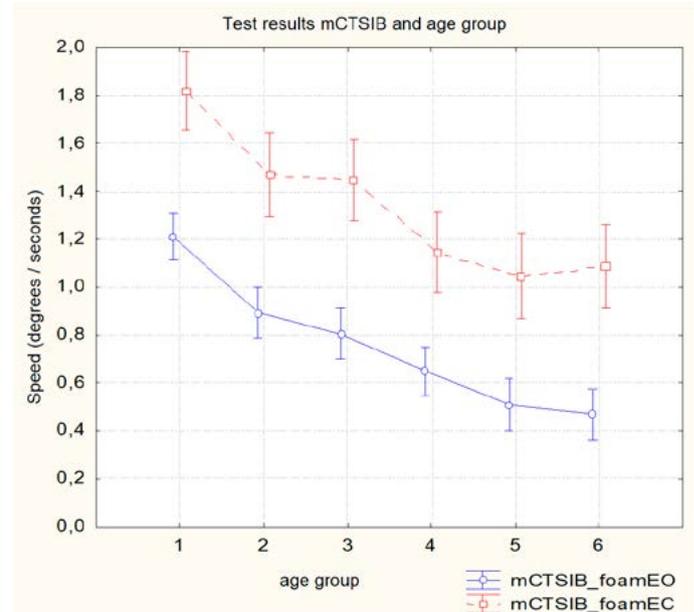
Tab. II. presents the average values of the centre of gravity tilt speeds along with the standard deviation in four different sensory conditions of the mCTSIB test in individual age groups. Tab. III. presents the values of the Romberg coefficient in the age groups.

Romberg index (from companies) ranged from 1.32 in the youngest group to 1.5 in children aged 16–17 (Tab. III.), while in the 14–15 age group (group V) there was a significant increase in its value and stabilisation in the next age group. The value of the index at this age was significantly higher than in groups I–IV ($p = 0.04$), which could suggest a growing share of sight in the control of posture with age.

Analysis of mCTSIB results based on sex showed significantly worse stability in boys from 6 to 11 years of age (groups 1–3) compared with girls (firm EC and firm EC) ($p = 0.01$). With limited access to proprioceptive information with preserved visual control (foam EO) and after its exclusion (foam EC), the stability of boys from 6 to 13 years of age (groups I to IV) was significantly lower than in girls ($p < 0.01$). After excluding visual information (foam EC), boys aged 16–17 (group VI) were less stable than girls of the same age ($p < 0.009$).

Findings and discussion

The mCTSIB test demonstrated a systematic improvement of postural stability with age in all sensory conditions, manifested by a decrease in the mean values of the centre of gravity tilt speed in



Ryc. 2. Average values of body tilt speed in °/s when standing on unstable ground with eyes open (foam EO) and closed (foam EC) across age groups.

the examined children. This dependence was also observed by other researchers [1, 7, 8, 10, 12, 18, 22, 26, 28, 31, 34, 36]. Analysing the changes in the parameters examined with age, it was found that the development of postural control in children is not linear. What is noticeable is the significantly poorer stability of children aged 6–7 (Group I) and significant improvement after the age of 7. Another significant improvement in stability appeared in the 12–13 age group (group IV). At the age of thirteen, no significant changes in parameters were found in any of the sensory conditions studied.

Similar observations indicating the stage development of postural control were made by other authors, although probably due to different research methodologies and perhaps also population and development differences, the given age of significant improvement in postural control in children is varied [6, 22, 31, 33]. In Baumberger et al., the accelerated development period is between 8 and 10 years of age and, according to Szmíd et al., between 7 and 11 years of age [5, 33]. Rival et al., when investigating children aged 6, 8 and 9 years found a non-monotonic decrease of the centre of gravity tilts with a maximum at the age of 8 and a linear decrease in postural velocity from 6–10 years of age [31]. In turn, Dos Santos Cardoso de Sa et al. found a significant improvement in stability between 5 and 7 years of age [10]. Kirshenbaum et al. indicated that young children use a non-feedback balance in control, an open-loop strategy, performing fast and wide centre of gravity corrections. Between 7 and 9 years of age, integration between the open and closed loop strategy develops, which results in improved postural control at that time [22]. In this context, the recorded significant improvement in stability after the age of 7 may also be associated with the development of a more mature type of postural control strategy in this period.

A separate issue is the degree of development and participation of individual sensory information in maintaining balance, especially in the youngest children [2, 3, 5–7, 10, 12, 13, 15–20, 23, 29,

Tab. I. MCTSIB test—a summary of sensory conditions in which there were significant differences in postural velocity between age groups.

GROUPS/ AGE BRACKET	I 6–7	II 8–9	III 10–11	IV 12–13	V 14–15	VI 16–17
I	-	-	-	-	Firm EO	Firm EO
6–7 years	-	Firm EC	Firm EC	Firm EC	Firm EC	Firm EC
	-	Foam EO	Foam EO	Foam EO	Foam EO	Foam EO
	-	Foam EC	Foam EC	Foam EC	Foam EC	Foam EC
	-	-	-	-	-	-
II	-	-	-	-	Firm EO	Firm EO
8–9 years	-	-	-	Firm EC	Firm EC	Firm EC
	-	-	-	Foam EO	Foam EO	Foam EO
	-	-	-	Foam EC	Foam EC	Foam EC
	-	-	-	-	-	-
III	-	-	-	-	-	Firm EO
10–11 years	-	-	-	-	-	Firm EC
	-	-	-	-	Foam EO	Foam EO
	-	-	-	Foam EC	Foam EC	Foam EC
	-	-	-	-	-	-
IV	-	-	-	-	Firm EO	Firm EO
12–13 years	-	-	-	-	-	-
	-	-	-	-	-	Foam EO
	-	-	-	-	-	-
	-	-	-	-	-	-
V	-	-	-	-	-	-
14–15 years	-	-	-	-	-	-
	-	-	-	-	-	-
	-	-	-	-	-	-
	-	-	-	-	-	-
VI	-	-	-	-	-	-
16–17 years	-	-	-	-	-	-
	-	-	-	-	-	-
	-	-	-	-	-	-
	-	-	-	-	-	-

39, 32, 34, 35]. The exclusion of visual control in the conditions of access to all sensory information did not significantly affect the deterioration of balance in children, except for the youngest group, whereas the restriction of proprioceptive information significantly worsened postural stability in all subjects, in particular after excluding visual control and in young children. The influence of visual information in postural control in children of different ages was assessed by a few authors using different methodologies. Deschamps et al. demonstrated the inability to maintain the balance of all subjects aged 6–7 after closing their eyes in the one leg standing test [9]. Nolan et al. observed the effect of excluding vision on postural stability, similar to that observed in adults, only in girls over 13 years old and in a group of boys aged 9–10 [28].

On the contrary, Ferbert-Viart et al. found children aged 6–14 to have a similar degree of use of visual information as adults at the age of 20, while having lower coefficients of sensory balance organisation. These coefficients worsened even in the absence of visual information, which the authors associated with incomplete development of the vestibular system and central integration in the nervous system [12]. This opinion is shared by Dos Santos Cardoso de Sa et al. and Cumberworth et al. according to whom the visual system matures as the first around the age of 5, followed by the proprioceptive system, and the vestibular as the last [8, 10]. According to Steindl et al., the mechanisms of proprioception mature between 3 and 4 years and those of the visual and vestibular

system up to 15–16 years [34]. Charpiot et al. reported an increase with age in the global balance score of children aged 6–12 in the sensory organisation test, with the analysis of each of the postural control components displaying an increase only in the vestibular control score. Functions: somatosensory and visual were comparable in all age groups [7].

The above observations suggest that a significant deterioration of the balance after excluding visual control in the youngest children in the mCTSIB test indicates immaturity in the functions of other systems, and does not result from its greater role in maintaining stability in this age, which is also confirmed by lower Romberg values compared to older children. An additional factor that hinders the interpretation of postural control results in the youngest children, as some reports indicate, is that young children use sensory information in a different way than adults, and the development of the balance system in its various aspects does not progress linearly with age [2, 3, 23, 25, 29, 30, 33].

After analysing the mCTSIB test results no significant changes in postural velocity under various sensory conditions were found in children after the age of 13, which suggests completion of the study function. In other reports, the arrangements regarding the time of reaching maturity in the field of postural control vary, which may result from different research methodology. According to Rival et al., it is the age of 9–10, Baumberger et al. 8–10 years [5, 31]. Barozzi

et al. believe that postural stability does not reach the level of adults even in children aged 13–14 [4].

In the work, the results of the mCTSIB test were also analysed based on gender. In reports there prevails a view that younger boys present less postural stability than girls, which was also confirmed by the results presented in [26, 28, 29, 34]. The stability of girls was found as greater in comparison to boys in all sensory conditions: up to 11 years of age in conditions of firm base (Firm EO and Firm EC), up to 13 years with limited proprioception with visual inspection (Foam EO) and up to 17 years after the exclusion of visual inspection (Foam EC).

Similar results were presented by other authors. Nolan et al. found higher values of postural tilts in static tests in boys up to the age of 10, with a significant improvement in stability after the age of this age. In girls aged 9–16, they found a minor relationship between postural control and age [28]. In turn, Steindl et al. found that girls achieve better parameters of postural control than boys up to 11–12 years old [34]. In the studies of Geldhof et al., girls aged 9–10 displayed better values in dynamic tests than boys of the same age [14].

CONCLUSIONS

The following conclusions were formulated on the basis of the conducted research:

1. The development of postural control in healthy Polish children aged 6–17 progresses nonlinearly, with a period of significant

Tab. II. mCTSIB test – a summary of the average tilt speed values of the centre of gravity in °/s across the age groups during different test conditions (firm base, eyes open – firm EO, eyes closed – firm EC, unstable base, eyes open – foam EO and closed – foam EC). In brackets – standard deviation.

AGE GROUP	MCTSIB FIRM EO	MCTSIB FIRM EC	MCTSIB FOAM EO	MCTSIB FOAM EC
I	0.7 (0.3)	0.92 (0.56)	1.2 (0.44)	1.8 (0.51)
II	0.4 (0.16)	0.53 (0.22)	0.89 (0.21)	1.47 (0.48)
III	0.3 (0.16)	0.43 (0.17)	0.8 (0.29)	1.43 (0.45)
IV	0.29 (0.1)	0.35 (0.12)	0.65 (0.15)	1.14 (0.39)
V	0.22 (0.1)	0.3 (0.12)	0.51 (0.1)	1.04 (0.35)
VI	0.15 (0.06)	0.2 (0.08)	0.47 (0.14)	1.08 (0.42)

Tab. III. The average values of Romberg index on firm ground (firm).

ROMBERG INDEX	I (SD)	II (SD)	III (SD)	IV (SD)	V (SD)	VI (SD)	TOTAL (SD)
firm	1.32 (0.38)	1.26 (0.5)	1.4 (0.51)	1.23 (0.27)	1.57 (0.8)	1.5 (0.65)	1.38 (0.54)

improvement in parameters in the mCTSIB test between 6–7 and 8–9 years of age and is completed up to the age of 13;

2. Girls are characterised by significantly better postural stability compared to boys of the same age; hence it seems reasonable to adopt separate normative values to assess the development of postural control in girls and boys.

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Corresponding author: Dr hab. n. med. Krystyna Orendorz-Frączkowska; Chair and Clinic of Otolaryngology, Head and Neck Surgery, Medical University of Wrocław, Wrocław, Poland; E-mail: kfraczkowska@wp.pl

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