

Effects of a 6-month balance intervention on postural control of preschoolers born with biological risk factors

Zsolt Csirkés¹, Károly Bretz², Katalin Jakab³, Rita F Földi⁴, Pál Hamar¹

¹Department of Gymnastics, RG, Dance and Aerobics, University of Physical Education, Budapest, Hungary; ²Department of Biomechanics, University of Physical Education, Budapest, Hungary; ³Faculty of Social Sciences, Eötvös, Loránd University, Budapest, Hungary; ⁴Department of Developmental Psychology, Károli Gáspár University of the Reformed Church in Hungary, Budapest, Hungary

Summary

Study aim: To investigate the effects of 6-month sensorimotor training on postural control of 5–6-year-old preschool children born with ‘biological risk factors’ (BRF).

Material and methods: Sixty-four Hungarian preschoolers participated in this study, and were assigned to an experimental group (n = 17), control group 1 (n = 23) and control group 2 (n = 24). The experimental group (born with BRF) attended a 6-month balance intervention based on Ayres’ therapy, while control group 1 (born with BRF) and control group 2 (born with no BRF) followed the regular preschool schedule. Birth weight, gestational age at birth, Apgar score and other abnormalities during pregnancy and birth were considered to be BRF. A moveable platform (stabilometer) was used to examine the distance of center of pressure movements of all participants prior to the start and after the end of the intervention. The testing procedure was performed with four enjoyable tests in the same sequence (‘Mouse in the hole’, ‘Center’, ‘Christmas tree’, ‘Square painting’).

Results: The balance intervention program resulted in significant improvements in postural control of the experimental group. In three of six variables the balance index scores of the intervention group approached the scores of their peers born without BRF, and they even had better performance in three of six variables.

Conclusions: Balance training with instability training devices could help children born with BRF attain a higher level of integration through the stimulation of tactile and balancing senses.

Keywords: Postural control – Unstable surface – Balance training – Biological risk factor – Stabilometer – Preschool children

Introduction

Researchers have been aware of the importance of motor development since the 1990s. Bushnell and Boudreau [10] stated that motor development plays a role in the development of cognitive and learning abilities. Wrobel [78] found a positive correlation between the speed of motion and IQ, and Wassenberg et al. [76] related visual motor integration to working memory.

Nowadays, the relationship between movement maturation and maturation of the central nervous system (CNS) and cognitive functions is the basis of many studies. Son and Meisels [69] have shown that visual motor skills are predictors of mathematical and reading performance [19]. Gross motor skills are needed

to stabilize and control the body and objects during the exploration of the environment. Later, fine motor skills are necessary to develop basic skills [12]. The relationship between motion control and maturation of the CNS was analyzed by applying specific motor tests (Zurich Neuromotor Assessment), from the aspect of speed of execution and forced movements in subjects aged 5–18 years [40, 43].

Stimulation of the balance system has a positive effect on the maturation processes and, as a result, biochemical processes can be activated in the brain [33, 59]. Developmental delay or atypical motor development indicates the differences, immaturity and/or early damage of the maturity of the CNS. As a result of developmental delay, complex learning problems and behavioral and neurocognitive disorders may develop [8, 45], which can be treated

by movement therapies. Therapies are only effective until neural reorganization is completed [2, 8, 45].

Ayres [4, 5] emphasizes the role of sensory integration in the development of neurological disorders. Uninterrupted sensory integration can only be established when the process is accompanied by appropriate movement [5]. Psychological aspects of the experiences coming from tactile, vestibular and proprioceptive stimulation create an opportunity for integration [3]. Ayres's sensory integration therapy uses a lot of unstable equipment and devices (e.g. trampolines, balance pads, seating discs, seesaws). Among the pieces of equipment the trampoline was mostly used as part of the intervention program [1, 9, 11, 14, 16, 31, 32, 47, 48]. These therapeutic devices are good to develop balancing ability, postural control, proprioception and coordination [1, 20, 42].

Postural control is defined as a perceptual-motor process which includes positioning and motion perception in visual, somatosensory and vestibular systems, as well as the processing of sensory information and the selection of motor response [56]. It involves the control of the body position in space to obtain stability and orientation [46]. Stability performance can be influenced by physical growth characteristics for children [15, 22, 26, 35, 37, 39, 54, 59, 66, 70, 71, 72, 73, 79, 80]. It was also found that age showed a more evident relationship with postural stability than gender [18, 24, 51]. Shintaku et al [67] reported that physical stability was independent of physical fitness in 4-6-year-old children. Riach [60] confirmed that children are less capable than adults of coordinating the anticipated postural adjustment due to longer reaction times and inconsistent postural responses.

Our study was conducted with preschoolers born with biological risk factors (BRF). The term 'biological risk factor' is well known, as it has been used in several studies [25, 34, 49, 55, 63, 74, 75, 77]. BRF include perinatal and postnatal growth, nutritional deficiencies, infectious diseases and environmental toxins [74].

This study aimed at investigating the effects of instability training devices on postural control in 5–6-year-old preschoolers born with BRF. Our hypotheses were as follows:

- 1) Prior to the intervention, the preschoolers born with BRF have decreased postural control compared to their peers who do not have any BRF.
- 2) After the intervention, postural control of the preschoolers involved in the development and born with BRF will improve more compared to their peers who have BRF but do not attend the training.
- 3) Postural control of the preschoolers attending the intervention will be similar to those of their peers born with no BRF.

Materials and methods

Participants

Sixty-four 5–6-year-old Hungarian preschoolers from districts I, II and XII of Budapest participated in this study. A case study from the parents was used to separate the preschoolers and assign them to three groups: the experimental group (EG, $n = 17$, mean age = 5.31 ± 0.55), in which preschoolers born with BRF attended a 6-month balance intervention based on Ayres therapy; control group 1 (CR1, $n = 23$, mean age = 5.53 ± 0.51), in which individuals born with BRF did not attend the training; control group 2 (CR2, $n = 24$, mean age = 5.70 ± 0.39), in which children born without BRF also did not attend the balance development. CR1 and CR2 groups followed the regular physical education schedule. Age, height, weight, birth weight, gestational age at birth and Apgar score values are represented in Table 1. Children born with BRF were divided into two groups (EG and CR1) by a simple random sampling. The research plan was accepted by the Regional, Institutional Science and Research Ethics Committee of Semmelweis University, Budapest, Hungary. This decision was based on Act CLIV of 1997 on healthcare. Each preschooler's

Table 1. Age, height, weight, birth weight, gestational age at birth and Apgar score values for EG, CR1 and CR2 groups

	Experimental group ($n = 17$) (EG, biological factors) (10 male, 7 female preschoolers)	Control group 1 ($n = 23$) (CR1, biological factors) (12 male, 11 female preschoolers)	Control group 2 ($n = 24$) (CR2, no biological factors) (12 male, 12 female preschoolers)
Age [year]	5.31 ± 0.55	5.53 ± 0.51	5.70 ± 0.39
Height [m]	1.15 ± 0.06	1.20 ± 0.04	1.22 ± 0.02
Weight [kg]	20.71 ± 3.50	20.52 ± 2.35	21.78 ± 1.63
Birth weight [g]	3009.41 ± 683.63	2961.30 ± 694.04	3199.79 ± 298.34
Gestational age at birth [week]	37.58 ± 2.83	37.94 ± 4.09	39.73 ± 0.73
Apgar score	9.05 ± 0.65	8.56 ± 1.23	9.50 ± 0.51

biological factor represented a score according to parental medical history. The scores were determined according to a scoring system of high-risk pregnancy [25]. Only factors during pregnancy and birth were considered. Within the groups the mean scores of BRF were calculated; the EG group (n = 17) had a score of 11.82, while the CR1 group (n = 23) had a score of 8.69. A score of 10 or more means high risk [25]. The most common BRF were preterm birth, Cesarean section, gestational diabetes, and premature detachment of the placenta.

Procedures

Measurements: All participants were tested prior to the start and after the end of the intervention. The testing apparatus was a moveable force platform (stabilometer), with a Bretz-König German patent, which is the property of the University of Physical Education, Department of Biomechanics. The linearity and hysteresis of the platform are 1.5%, and the horizontal resolution is 1 mm. The connecting device can be any personal computer that receives these signals. The size is 50 × 50 cm and the weight is 15 kg.

Four stabilometric tests were used where preschoolers stood as still as possible on a stabilometer opposite a monitor with their arms placed downward at either side of the body, their bare feet less than shoulder-width apart. The tests were performed in the same sequence with the help of two skilled instructors. Preschoolers were asked to move their body backwards and forwards and laterally. Postural control was assessed with center of pressure excursions.

'Mouse in the hole': The aim was to maintain balance by moving a mouse seen on the monitor into an asymmetrically positioned hole. A maximum of 20 seconds was available for the task. The test was evaluated on the basis of an attempt with an accuracy of 1 second of the elapsed time.

'Center': The aim was to maintain balance by fixing a square in a target frame for 20 seconds. The actual center of gravity should be inside the center, within a certain tolerance of 15 mm. This is the exact size of the square seen on the screen. The program examines what percent of the tested time the square is fixed in the center.

'Christmas tree': The aim was to maintain balance by picking 6 candies from a Christmas tree seen on the monitor (Figures 1a, b, c). A maximum of 20 seconds was available for the task. The test was evaluated on the basis of an attempt with an accuracy of 1% of success and 1 second of elapsed time.

'Square painting': The aim was to maintain balance by painting a square seen on the monitor (Fig. 2). A maximum of 20 seconds was available for the task. The program examined two pieces of data: what percentage of the square in the center of the monitor was painted, and what percentage of the given time the center of gravity remained inside the target frame.

Training program: The balance intervention was based on the principles of Ayres therapy where we created a colorful set full of different instability training devices. The sessions were held in a gym in the city center of Budapest, with the help of four instructors (two skilled

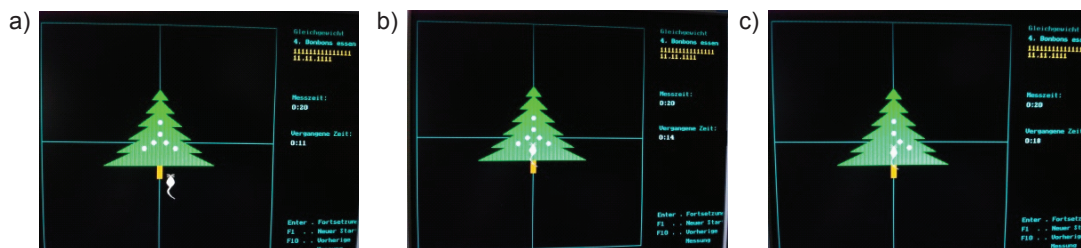


Fig. 1. The aim of the ‘*Christmas tree*’ test was to pick candies from a Christmas tree by moving the center of gravity (a mouse can be seen approaching the tree; the mouse is already on the tree; the mouse has swallowed some candies)



Fig. 2. A preschooler is performing the ‘*Square painting*’ task while standing on a stabilometer

PE teachers and two students of the University of Physical Education). The children took part in 2×30 -minute sessions a week for six months. Prior to the first session, we gave the parents a brochure in which the purposes, requirements and tasks were described. The instructors recorded the information when the child completed a level. Four stations were built by using various devices and were given funny names: '*Bouncing flea*' (mini-trampolines); '*Flying rubber belt*' (an inner tube hanging from the ceiling); '*Colorful gummy berries*' (therapy balls, peanut balls, doughnut balls); '*Magical rubber forest*' (seating discs, hemispherical massage balls, balance pads). Five development levels to be reached were determined for every station, which were shown by different colors. The requirements of each task of the appropriate level were determined, which means that children could only switch level (color) if they fulfilled the requirements of the previous one.

Statistical analysis

The paired sample t-test was used to investigate the differences between pre- and post-tests. To test the pre-requisites required to carry out t-tests, we first performed normality and homogeneity of variance tests. In cases where the conditions were not met, non-parametric methods were used. The Wilcoxon test was applied to obtain the differences in performance between pre- and post-tests. Descriptive statistics of the tests (case number, mean, standard deviation) and correlations between variables were calculated. Differences between the group results were tested with one-way ANOVA, in which the values of the F-test or Welch test were examined depending on the fulfillment of the test of homogeneity of variance. Correlation was also used to predict the relationship between pre- and post-tests

of the groups. The analysis was conducted using the IBM SPSS Statistics 22 software.

Results

Table 2 shows the descriptive statistics of the six different measurements. The first column shows the average results of pre-tests of the preschoolers born with biological risk factors (EG and CR1 groups). This is followed by the average results of the three groups separately. Table 3 summarizes the results of the independent samples t-tests, which show that the weaker performance of preschoolers born with biological factors was statistically significant in the variable '*Square painting-success*', at a 5% significance level. Thus, for the other tasks, the performance of preschoolers born with risk factors is weaker, but the difference is not significant in comparison to the results of their peers born without any risk factors.

'Mouse in the hole': Time results were analyzed and compared in seconds (Table 2). Table 4 shows that a significant correlation can only be observed between the two measurements of the CR1 group ($R_{CR1} = 0.598$, $p = 0.003$). A significant difference was noted between the two measurements in all the three groups (Table 6). The CR2 group could move the mouse into the hole 1.96 ± 3.7 seconds faster ($W = -2.449$, $p = 0.014$) compared to pre-test, while the CR1 group could do it $2.22 (\pm 3.1)$ seconds faster ($W = -2.918$, $p = 0.004$), and the EG group 3.53 ± 5.1 seconds faster ($W = -2.884$, $p = 0.004$). So the greatest average improvement was observed for the EG group.

'Center': We measured and compared the success rate, which was determined as a percentage (Table 2). For all three groups there is a significant correlation between the

Table 2. Descriptive statistics for EG, CR1 and CR2 groups

	Risk groups (n = 40)			EG group (n = 17)		CR1 group (n = 23)		CR2 group (n = 24)	
	Pre			Pre	Post	Pre	Post	Pre	Post
	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD	Mean $\pm$ SD
Mouse in the hole [time, sec]	6.25 $\pm$ 4.5	7.06 $\pm$ 5.2	3.53 $\pm$ 1.3	5.65 $\pm$ 3.9	3.43 $\pm$ 2.2	5.88 $\pm$ 3.7	3.92 $\pm$ 1.2		
Center [success, %]	85.52 $\pm$ 22.5	81.59 $\pm$ 21.8	93.29 $\pm$ 9.6	88.43 $\pm$ 23	96.22 $\pm$ 7.2	93.17 $\pm$ 12	97.5 $\pm$ 4.5		
Christmas tree [success, %]	96.22 $\pm$ 10.3	97.06 $\pm$ 8.8	100 $\pm$ 0	95.61 $\pm$ 11.5	100 $\pm$ 0	99.29 $\pm$ 3.5	99.29 $\pm$ 3.5		
Christmas tree [time, sec]	10.4 $\pm$ 5	9.71 $\pm$ 4.8	7.82 $\pm$ 3.5	10.91 $\pm$ 5.2	8.87 $\pm$ 3.4	9.38 $\pm$ 3.6	8.67 $\pm$ 4.1		
Square painting [success, %]	49.25 $\pm$ 13	52.41 $\pm$ 12.1	58.35 $\pm$ 12.9	46.91 $\pm$ 13.5	51.61 $\pm$ 10.9	57.38 $\pm$ 12.1	55.71 $\pm$ 9.3		
Square painting [time, %]	80.17 $\pm$ 20.5	73.41 $\pm$ 21.3	87.35 $\pm$ 8.4	85.17 $\pm$ 18.7	88.26 $\pm$ 11.3	85.96 $\pm$ 13.4	90.71 $\pm$ 4.7		

Table 3. Group differences with Independent-Samples T-Test

	Levene's test for equality of variances		t-test for equality of means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% Confidence interval of the difference	
								Lower	Upper
Mouse in the hole pre test									
Risk vs. no risk [time, sec]	0.393	0.533	−0.345	62	0.731	−0.375	1.087	−2.547	1,797
Center pre test									
Risk vs. no risk [success, %]	5.247	0.025	1.768	61	0.082	7.642	4.323	−1.001	16,284
Christmas tree pre test									
Risk vs. no risk [success, %]	8.626	0.005	1.720	52	0.091	3.067	1.783	−0.511	6,644
Risk vs. no risk [time, sec]	4.502	0.038	−0.955	60	0.343	−1.025	1.073	−3.171	1,121
Square painting pre test									
Risk vs. no risk [success, %]	0.832	0.365	2.474	62	0.016*	8.125	3.285	1.559	14,691
Risk vs. no risk [time, %]	4.365	0.041	1.363	61	0.178	5.783	4.244	−2.701	14,268

* – The significance level is 0.05.

Table 4. Correlations for EG, CR1 and CR2 groups

	EG group pre & post (n = 17)		CR1 group pre & post (n = 23)		CR2 group pre & post (n = 24)	
	Correlation	Sig.	Correlation	Sig.	Correlation	Sig.
Mouse in the hole [time, sec]	0.203	0.434	0.598	0.003*	0.162	0.45
Center [(success, %]	0.686	0.002*	0.923	0.000*	0.709	0.000*
Christmas tree [success, %]	–	–	–	–	–	–
Christmas tree [time, sec]	0.202	0.436	0.181	0.41	0.515	0.010*
Square painting [success, %]	0.754	0.000*	0.177	0.42	0.138	0.521
Square painting [time, %]	0.001	0.997	0.614	0.002*	0.133	0.537

* – The significance level is 0.05.

results of the two measurements (Table 4). Table 6 shows that on the basis of the results of the Wilcoxon test, with 95% confidence, a statistically significant difference was found between the results of pre – and post-tests of all three test groups. Compared to the pre-test, the CR2 group was $4.33 \pm 9.4\%$ more successful ($W = 2.53$, $p = 0.011$) in keeping the square in the target frame; for the CR1 group it was $7.78 \pm 16.6\%$ ($W = 2.435$, $p = 0.015$); and for the EG group it was $11.71 \pm 16.8\%$ ($W = 2.544$, $p = 0.011$). The greatest improvement was also observed in the EG group.

'Christmas tree': The EG group was on average $2.94 \pm 8.8\%$ more successful and 1.88 ± 5.3 seconds faster than during the pre-test (Table 2). In the CR1 group, the success rate increased by an average of $4.39 \pm 11.5\%$ and the time result improved by 2.04 ± 5.6 s. The success rate of the CR2 group did not change; the time result was 0.71 ± 3.8 s faster. With 95% confidence, based on the paired samples t-test (Table 5) and the significance of the Wilcoxon signed rank test (Table 6), the differences were not statistically significant for the groups. However, during

Table 5. Pre and post test results with Paired Samples T-test

	Paired differences					t	df	Sig. (2-tailed)
	Mean	SD	Std. error mean	95% Confidence interval of the difference				
				Lower	Upper			
Christmas tree								
EG pre vs. EG post [time. sec]	1.882	5.337	1.294	-0.862	4.626	1.454	16	0.165
Square painting								
CR1 pre vs. CR1 post [success. %]	-4.696	15.769	3.288	-11.515	2.124	-1.428	22	0.167
CR2 pre vs. CR2 post [success. %]	1.667	14.239	2.907	-4.346	7.679	0.573	23	0.572
EG pre vs. EG post [time. %]	-13.941	22.922	5.559	-25.727	-2.156	-2.508	16	0.023*

* – The significance level is 0.05.

Table 6. Pre and post test results with Related-Samples Wilcoxon Signed Rank Test

	EG pre vs. EG post (n = 17)			CR1 pre vs. CR1 post (n = 23)			CR2 pre vs. CR2 post (n = 24)		
	Test statistic	Std. test statistic	Asymtotic Sig. (2-sided test)	Test statistic	Std. test statistic	Asymtotic Sig. (2-sided test)	Test statistic	Std. test statistic	Asymtotic Sig. (2-sided test)
Mouse in the hole [time, sec]	7	-2.884	0.004*	23	-2.918	0.004*	46	-2.449	0.014*
Center [success, %]	93	2.544	0.011*	115	2.435	0.015*	143.5	2.53	0.011*
Christmas tree [success, %]	3	1.342	0.18	10	1.89	0.059	–	–	–
Christmas tree [time, sec]		(t-test)		91.5	-1.139	0.255	92.5	-0.804	0.422
Square painting [success, %]	117	2.537	0.011*		(t-test)			(t-test)	
Square painting [time, %]		(t-test)		126	0.784	0.433	183.5	1.387	0.165

* – The significance level is 0.05

the post-test, EG and CR1 groups had 100% success in completing the task. In addition, the EG group had the best time results; they completed the task in 7.82 ± 3.5 s.

‘Square painting’: With a significance level of 0.05, only the differences between the results of the EG group are considered statistically significant ($W = 2.537$, $p = 0.011$; $t_{16} = -2.508$, $p = 0.023$). The EG group performed the ‘Square painting’ task $5.9 \pm 8.8\%$ more successfully during the post-test, thus making it the best among the groups (Table 2). And $13.9 \pm 22.9\%$ more of the given time they could keep their center of gravity inside the target frame.

In comparison, the CR1 group was on average $4.7 \pm 15.8\%$ more successful and could remain $3.1 \pm 14.8\%$ more of the given time within the frame. While the success of the performance of CR2 group deteriorated by an average $1.7 \pm 14.2\%$ in the post-test, they were able to keep their center of gravity in the frame more of the given time than in the pre-test, so the average success rate improved by $4.8 \pm 13.6\%$.

In the post-tests, one-way ANOVA was used to determine whether there was a significant difference between the three groups. According to the Levene test,

Table 7. Oneway ANOVA for post tests

	Test of homogeneity of variances		ANOVA		Robust tests of equality of means	
	Levene statistic	Sig.	F	Sig.	Welch statistic	Sig.
Mouse in the hole [time, sec]	0.982	0.380	0.561	0.573	0.681	0.512
Center [success, %]	5.188	0.008*	1.769	0.179	1.458	0.247
Christmas tree [success, %]	3.623	0.033*	0.829	0.441	–	–
Christmas tree [time, sec]	0.337	0.715	0.419	0.660	0.470	0.628
Square painting [success, %]	0.189	0.828	1.963	0.149	1.714	0.195
Square painting [time, %]	9.645	0.000*	0.881	0.420	1.344	0.275

* – The significance level is 0.05.

a significant difference can be observed in the variables 'Center', 'Christmas tree-success' and 'Square painting-success' among the standard deviations of the groups (Table 7). Therefore, the result of the Welch test and its significance are relevant, while for other measurements, where the scatter homogeneity ('Mouse in the hole', 'Christmas tree-time', 'Square painting-success') is satisfied, the significance of the F test will decide the test result. The tests did not show any significant difference between the mean results of the groups at a significance level of 0.05. To sum up, there was no significant difference between the EG and CR2 groups after the balance intervention.

Discussion

In the study, we were interested in knowing how a balance intervention based on Ayres therapy and done with instability training devices can have an effect on postural control of preschoolers born with BRF. The EG group attended six-month balance training, while the CR1 and CR2 groups followed the preschool schedule. Four enjoyable stabilometric tests were applied to examine postural control.

The balance intervention resulted in significant improvements in postural control of the EG group. In the variables 'Mouse in the hole', 'Center' and 'Square painting' the EG group achieved the greatest improvement compared to the CR1 and CR2 groups. However, in the variables 'Mouse in the hole' and 'Center' a statistically significant difference was observed between pre- and post-tests in all the three groups (EG, CR1 and CR2).

1) It was hypothesized that prior to the intervention, EG and CR1 groups had decreased postural control compared to the CR2 group. The first hypothesis proved to be true, since all the four tasks were actually performed more weakly by preschoolers born with BRF. However, the difference in performance was only significant in the 'Square painting-success' variable at a significance level of 0.05.

2) It was hypothesized that after the intervention, the postural control of the EG group would improve more compared to the CR1 group. This hypothesis is largely justified. In four out of six tests the EG group had indeed the best improvement in 'Mouse in the hole', 'Center', 'Square painting-success' and 'Square painting-time' variables.

3) Furthermore, it was hypothesized that after the intervention, postural control of the EG group would be similar to that of the CR2 group. In two of six variables ('Center', 'Square painting-time success') the balance scores of the EG group approached the scores of their peers born without BRF and they even had better performance in four out of six variables ('Mouse in the hole', 'Christmas tree-success', 'Christmas tree-time', 'Square painting-success'). There was no significant difference in either case. The hypothesis was supported.

After sensorimotor therapy children from the experimental group did 'catch up' the children born with no BRF [53]. The instability training devices seem to have an effect on children's postural control. These devices could help the children born with BRF to attain a higher level of integration through the stimulation of tactile and balancing senses. Research shows that these special devices effectively improve balance and postural control [11, 13, 15, 32, 41, 42, 47, 52, 64]. Between five and six years, children seem to be learning how to integrate sensory information and how to calibrate sensory feedback in postural control [64]. It is suggested that this age is a transition period in the development of postural control [68]. It is likely that task difficulty and the availability of sensory information influence postural control [30].

Only risk factors during pregnancy and birth were considered. Therefore, we can conclude that premature birth is the most common perinatal risk that endangers normal development. Processes of the information processing system (attention, processing speed) are also different for a premature child, and this can lead to a subsequent

cognitive deficit [62]. Preterm children are more likely to have learning disabilities and poor school performance [65]. Premature birth affects the ability to maintain body balance [21]. Parental involvement is essential in the preventive treatment of a child's sensomotoric, social-emotional and cognitive-linguistic development [74].

A similar study was conducted, measuring postural control in 6-8-year-old children with attention deficit hyperactivity disorder (ADHD) with these stabilometric tests [29]. It was found that the delay of maturity was not manifested in the speed of movements. 8.66 s was observed in the 'Christmas tree' test and 4.6 s in the 'Mouse in the hole' test compared to our EG group (7.82 s and 3.53 s, respectively).

Other investigations highlighted postural instabilities with higher center of pressure excursions in children with autism spectrum disorder [27, 50], cerebral palsy [23], developmental coordination disorder [30, 38, 44] and visual impairment [57]. It is likely that task difficulty and availability of sensory information will influence the quality of postural control [30].

Studies show that interventions have positive effects on subjects' postural control. Active trial and error experiences may improve postural control in children with high risk for a developmental motor disorder. [18]. Postural control results assessed by center of pressure values showed that 5-6-year-old children involved in circus activities and doing static and dynamic tasks in challenging conditions had better performances than control group children [64]. Exercise intervention focused on the enhancement of sensory integrative postural control abilities was effective for decreasing motor development delay in children with sensorineural hearing loss and vestibular impairment [61].

The real value of this study is that adequate and safe implementation of functional movements can lead to the maturity of movement which means school readiness [7, 12].

Conclusions

As this was an impact assessment study, the difference between the experimental group and the control groups indicates the outcome of development. Exceeding the normal maturation processes is verified by the t-test and Wilcoxon test.

We speculate that if balance training had lasted longer, more significant results might have been achieved. It is likely that motor components of the children's lifestyle may also result in positive changes in postural control.

In order to obtain a more comprehensive picture of preschoolers' development, future research on the following issues is necessary: visual perceptual test [28]; concentration and attention (deficit) assessment [6]; bilateral

integration assessment (Sensory Integration and Praxis Test-SIPT) [4]; crossing mid-line test [58]; hand-eye coordination test [36].

Conflict of interest: Authors state no conflict of interest.

References

1. Aragao F.A., Karamanidis K., Vaz M.A., Arampatzis A. (2011) Mini-trampoline exercise related to mechanisms of dynamic stability improves the stability to regain balance in elderly. *J. Electromyogr. Kinesiol.*, 21(3): 512-518. DOI: 10.1016/j.jelekin.2011.01.003.
2. Arya K.N., Pandian S., Verma R., Garg R.K. (2011) Movement therapy induced neural reorganization and motor recovery in stroke: a review. *J. Bodyw. Mov. Ther.*, 15(4): 528-537. DOI: 10.1016/j.jbmt.2011.01.023.
3. Ayres A.J. (1979) Lernstörungen: Sensorisch-integrative Dysfunktionen. [Learning Disorders: Sensory-integrative dysfunctions]. Heidelberg.
4. Ayres A.J. (1989) Sensory Integration and Praxis Test (SIPT). www.wpspublish.com/store/p/2971/sipt-sensory-integration-and-praxis-tests
5. Ayres A.J., Robbins J. (2005) Sensory Integration and the child: Understanding hidden sensory challenges. (25th Anniversary Edition). Los Angeles, CA: WPS.
6. Barkley R.A. (1990) Attention-deficit hyperactivity disorder: A handbook for diagnosis and treatment. Guilford, New York.
7. Birontiené Z. (2010) Changes in the physical fitness of 5 to 7-year-old-children in the promotion of their physical maturing for school. *Bridges/Tiltai*, 4: 133-143.
8. Blazer D. (2013) Neurocognitive disorders in DSM-5. *Am. J. Psychiatry*, 6: 585-587. DOI: 10.1176/appi.ajp.2013.13020179.
9. Bumin G., Kayihan H. (2001) Effectiveness of two different sensory-integration programmes for children with spastic diplegic cerebral palsy. *Disabil. Rehabil.*, 23(9): 394-399. DOI: 10.1080/09638280010008843.
10. Bushnell E.W., Boudreau J.P. (1993) Motor development and the mind: The potential role of motor abilities as a determinant of aspects of perceptual development. *Child Dev.*, 64(4): 1005-1021. DOI: 10.2307/1131323.
11. Cheldavi H., Shakerian S., Boshehri S.N.S., Zarghami M. (2014) The effects of balance training intervention on postural control of children with autism spectrum disorder: Role of sensory information. *Res. Autism Spectr. Disord.*, 8: 8-14. DOI: 10.1016/j.apmr.2017.02.032.
12. Cools W., De Martelaer K., Semaey C., Andries C. (2009) Movement skill assessment of typically developing preschool children: A review of seven movement skill assessment tools. *J. Sports Sci. Med.*, 8: 154-168.

13. Cornilleau-Peres V., Shabanac N., Droulez J., Gohe J.C.H., Lee G.S.M., Chew P.T.K. (2005) Measurement of the visual contribution to postural steadiness from the COP movement: Methodology and reliability. *Gait Posture*, 22: 96-106. DOI: 10.1016/j.gaitpost.2013.09.016.
14. Crowther R.G., Spinks W.L., Leicht A.S., Spinks C.D. (2007) Kinematic responses to plyometric exercises conducted on compliant and noncompliant surfaces. *J. Strength Cond. Res.*, 21(2): 460-465. DOI: 10.1519/R-19645.1.
15. Cumberworth V.L., Patel N.N., Rogers W., Kenyon G.S. (2007) The maturation of balance in children. *J. Laryngol. Otol.*, 121(5): 449-454. DOI: 10.1017/S002225106004051.
16. De Castro Ferracioli M., Yukiko Hiraga C., Pellegrini A.M. (2014) Emergence and stability of interlimb coordination patterns in children with developmental coordination disorder. *Res. Dev. Disabil.*, 35(2): 348-356. DOI: 10.1016/j.ridd.2013.11.002.
17. De Graaf-Peters V.B., Blauw-Hospers C.H., Dirks T., Bakker H., Bos A.F., Hadders-Algra M. (2007) Development of postural control in typically developing children and children with cerebral palsy: possibilities for intervention? *Neurosci. Biobehav. Rev.*, 31(8): 1191-1200. DOI: 10.1016/j.neubiorev.2007.04.008.
18. De Oreo K., Wade M.G. (1971) Dynamic and static balancing ability of preschool children. *J. Motor Behav.*, 3: 326-335. DOI: 10.1080/00222895.1971.10734913.
19. Donnelly J.E., Lambourne K. (2011) Classroom-Based Physical Activity, Cognition, and Academic Achievement. *J. Prev. Med.*, 52: S36-S42. DOI: 10.1016/j.ypmed.2011.01.021.
20. Drinkwater E.J., Pritchett E.J., Behm D.G. (2007) Effect of Instability and Resistance on Unintentional Squat-Lifting Kinetics. *Int. J. Sports Med.*, 2(4): 400-413. DOI: 10.1123/ijspp.2.4.400.
21. Dziuba E., Drzal-Grabiec J., Truszczyńska-Baszk A., Guzek K., Zajkiewicz K. (2017) Balance in children born prematurely currently aged 6–7. *Biomed. Hum. Kinetics*, 9(1): 181-186. DOI: 10.1515/bhk-2017-0025.
22. Erbaugh S.J. (2013) The relationship of stability performance and the physical growth characteristics of preschool children. *Res. Q. Exerc. Sport*, 1: 8-16. DOI: 10.1080/02701367.1984.10605349.
23. Ferdjallah M., Harris G.F., Smith P., Wertsch J.J. (2002) Analysis of postural control synergies during quiet standing in healthy children and children with cerebral palsy. *Clin. Biomech.*, 17(3): 203-210. DOI: 10.1016/S0268-0033(01)00121-8.
24. Figura F., Cama G., Capranica L., Guidetti L., Pulejo C. (1991) Assessment of static balance in children. *J. Sports Med. Phys. Fitness*, 31(2): 235-242.
25. Fletcher A.J., Edwards J.E., Cutler R.E., Rundio A.A., Hussar D.A., Rossi G.V., Bakris G.L. (2003) MSD Orvosi Kézikönyv a Családban. [MSD Medical Handbook in family]. Melancia Kiadó Kft., Budapest.
26. Foudriat B.A., Di Fabio R.P., Anderson J.H. (1993) Sensory organization of balance responses in children 3-6 years of age: a normative study with diagnostic implications. *Int. J. Pediatr. Otorhinolaryngol.*, 27: 255-271. DOI: 10.1016/0165-5876(93)90231-Q.
27. Fournier K.A., Kimberg C.I., Radonovich K.J., Tillman M.D. (2010) Decreased static and dynamic postural control in children with autism spectrum disorders. *Gait Posture*, 32: 6-9. DOI: 10.1016/j.gaitpost.2010.02.007.
28. Frostig M., Welty Lefever D., Whittlesey J.R.B. (1961) A developmental test of visual perception for evaluating normal and neurologically handicapped children. *Percept. Mot. Skills*, 12: 383-394. DOI: 10.2466/pms.1964.19.2.463.
29. Földi R., Boda Ujlaky J. (2014) Vestibular regulation in children with ADHD: a neuropsychological perspective. *Psychologia Hungarica*, 2: 66-74. DOI: 10.12663/Pyshung.2.2014.2.4.
30. Geuze R.H. (2005) Postural control in children with developmental coordination disorder. *Neural Plast.*, 12(2-3): 183-196. DOI: 10.1155/NP.2005.183.
31. Giagazoglou P., Kokaridas D., Sidiropoulou M., Patsiaouras A., Karra C., Neofotistou K. (2013) Effects of a trampoline exercise intervention on motor performance and balance ability of children with intellectual disabilities. *Res. Dev. Disabil.*, 34: 2701-2707. DOI: 10.1016/j.ridd.2013.05.034.
32. Giagazoglou P., Sidiropoulou M., Mitsiou M., Arabatzi F., Kellis E. (2015) Can balance trampoline training promote motor coordination and balance performance in children with developmental coordination disorder? *Res. Dev. Disabil.*, 36: 13-19. DOI: 10.1016/j.ridd.2014.09.010.
33. Goddard B.S. (2014) Neuromotor Immaturity in Children and Adults: The INPP Screening Test for Clinicians and Health Practitioners. John Wiley & Sons, Ltd, The Atrium, Southern Gate, Chichester, West Sussex.
34. Grantham-McGregor S., Cheung Y.B., Cueto S., Glewwe P., Richter L., Strupp B., International Child Development Steering Group (2007) Developmental potential in the first 5 years for children in developing countries. *The Lancet*, 369: 60-70. DOI: 10.1016/S0140-6736-(07)60032-4.
35. Hayes K.C. (1982) Biomechanics of postural control. In: R.L. Terjung (ed.) Exercise and sport science review, Franklin Institute, Syracuse, pp. 363-391.
36. Held R., Hein A.V. (1958) Adaptation of Disarranged Hand-Eye Coordination Contingent upon Re-Afferent Stimulation. *Percept. Mot. Skills*, 8: 87-90.
37. Hirabayashi S., Iwasaki Y. (1995) Developmental perspective of sensory organization on postural control. *Brain Dev.*, 17(2): 111-113. DOI: 10.1016/0387-7604-(95)00009-Z.

38. Johnston L.M., Burns Y.R., Brauer S.G., Richardson C.A. (2002) Differences in postural control and movement performance during goal directed reaching in children with developmental coordination disorder. *Hum. Mov. Sci.*, 21(5-6): 583-601. DOI: 10.1016/S0167-9457-(02)00153-7.
39. Jung H.K., Chung E., Lee B.H. (2017) A comparison of the balance and gait function between children with Down syndrome and typically developing children. *J. Phys. Ther. Sci.*, 29(1): 123-127. DOI: 10.1589/jpts.29.123.
40. Kakebeeke T.H., Locatelli I., Rousson V., Caflisch J., Jenni O.G. (2012) Improvement in gross motor performance between 3 and 5 years of age. *Percept. Mot. Skills*, 114(3): 795-806. DOI: 10.2466/10.13.25.PMS.114.3.795-806.
41. Kayapmar F.C. (2010) The Effect of the Movement Education on the Dynamic Balance Skills of Preschool Children. *World Appl. Sci. J.*, 10: 607-611.
42. Kidgell D.J., Horvath D.M., Jackson B.M., Seymour P.J. (2007) Effect of six weeks of dura disc and mini-trampoline balance training on postural sway in athletes with functional ankle instability. *J. Strength Cond. Res.*, 21(2): 466-469. DOI: 10.1519/R-18945.1.
43. Largo R.H., Caflisch J.A., Hug F., Muggli K., Molnar A.A., Molinari L. (2001) Neuromotor development from 5 to 18 years. Part 1: timed performance. *Dev. Med. Child Neurol.*, 43: 436-443. DOI: 10.1111/j.1469-8749.2001.tb00739.x.
44. Laufer Y., Ashkenazi T., Josman N. (2008) The effects of a concurrent cognitive task on the postural control of young children with and without developmental coordination disorder. *Gait Posture*, 27(2): 347-351. DOI: 10.1016/j.gaitpost.2007.04.013.
45. Livonen S., Sääkslahti A., Nissinen K. (2011) The development of fundamental motor skills of four – to five-year-old preschool children and the effects of a preschool physical education curriculum. *Early Child Dev. Care*, 181(3): 335-343. DOI: 10.1080/03004430903387461.
46. Massion J. (1998) Postural control systems in developmental perspective. *Neurosci. Biobehav. Rev.*, 22: 465-472. DOI: 10.1155/NP.2005.229.
47. Miklitsch C., Krewer C., Freivogel S., Steube D. (2013) Effects of a predefined mini-trampoline training programme on balance, mobility and activities of daily living after stroke: a randomized controlled pilot study. *Clin. Rehabil.*, 10: 939-947. DOI: 10.1177/0269215513485591.
48. Mikolajczyk E., Jankowicz-Szymanska A. (2015) Does extending the dual-task functional exercises workout improve postural balance in individuals with ID? *Res. Dev. Disabil.*, 38: 84-91. DOI: 10.1016/j.ridd.2014.12.008.
49. Minde K. (1993) Prematurity and serious medical illness in infancy: Implications for development and interventions. In C. H. Zeanah (ed.) *Handbook of Infant Mental Health*. The Guilford Press, New York.
50. Minshew N.J., Sung K., Jones B.L., Furman J.M. (2004) Underdevelopment of the postural control system in autism. *Neurology*, 63(11): 2056-2061. DOI: 10.1212/01.WNL.0000145771.98657.62.
51. Morris A., Williams J., Atwater A., Wilmore J. (1982) Age and sex differences in motor performance of 3 through 6 year old children. *Res. Quart. Exer. Sport*, 53: 214-221. DOI: 10.1080/02701367.1982.10609342.
52. Msall M.E. (2000) Genes, brains, and development: Linking preschool developmental disorders to medical science and care. *J. Pediatr.*, 137(5): 600-602. DOI: 10.1067/mpd.2000.111163.
53. Niklasson M., Norlander T., Niklasson I., Rasmussen P. (2017) Catching-up: Children with developmental coordination disorder compared to healthy children before and after sensorimotor therapy. *PLoS One*, 12(10): e0186126. DOI: 10.1371/journal.pone.0186126.
54. Odenrick P., Sandstedt P. (1984) Development of postural sway in the normal child. *Hum. Neurobiol.*, 3(4): 241-244.
55. Ozkan M., Senel S., Arslan E.A., Karacan C.D. (2012) The socioeconomic and biological risk factors for developmental delay in early childhood. *Eur. J. Pediatr.*, 171(12): 1815-1821. DOI: 10.1007/s00431-012-1826-1.
56. Pollock A.S., Durward B.R., Rowe P.J., Paul J.P. (2000) What is balance? *Clin. Rehabil.*, 14(4): 402-406. DOI: 10.1191/0269215500cr342oa.
57. Portfors-Yeomans C.V., Riach C.L. (1995) Frequency characteristics of postural control of children with and without visual impairment. *Dev. Med. Child Neurol.*, 37(5): 456-463. DOI: 10.1111/j.1469-8749.1995.tb12029.x.
58. Provine R.R., Westerman J.A. (1979) Crossing the Midline: Limits of Early Eye-Hand Behavior. *Child Dev.*, 50(2): 437-441.
59. Riach C.L., Hayes K.C. (1987) Maturation of postural sway in young children. *Dev. Med. Child Neurol.*, 29(5): 650-658.
60. Riach C.L., Hayes K.C. (1990) Anticipatory postural control in children. *J. Mot. Behav.*, 22(2): 250-266. DOI: 10.1080/00222895.1990.10735513.
61. Rine R.M., Braswell J., Fisher D., Joyce K., Kalar K., Shaffer M. (2004) Improvement of motor development and postural control following intervention in children with sensorineural hearing loss and vestibular impairment. *Int. J. Pediatr. Otorhinolaryngol.*, 68(9): 1141-1148. DOI: 10.1016/j.ijporl.2004.04.007.
62. Rose S.A., Feldman J.F., Jeffery J., Jankowski R., Van Rosem R. (2011) Basic information processing abilities to 11 years account for deficit in IQ. *Intelligence*, 39: 198-209. DOI: 10.1016/j.intell.2011.03.003.
63. Saccani R., Valentini N.C., Pereira K.R.G., Müller A.B., Gabbard C. (2013) Associations of biological factors and

- affordances in the home with infant motor development. *Pediatr. Int.*, 55(2): 197-203. DOI: 10.1111/ped.12042.
64. Sahli S., Ghroubi S., Rebai H., Chaabane M., Yahia A., Pérennou D., Elleuch M.H. (2013) The effect of circus activity training on postural control of 5-6-year-old children. *Sci. Sports*, 28(1): 11-16. DOI: 10.1016/j.scispo.2011.10.010.
 65. Saigal S., Hoult L.A., Streiner D.A., Stoskopf B.L., Rosenbaum P.L. (2000) School difficulties in adolescence in a regional cohort of children who were extremely low birth weight. *Pediatrics*, 105: 325-331.
 66. Shambes G.M. (1976) Static postural control in children. *Am. J. Phys. Med. Rehabil.*, 55(5): 221-252.
 67. Shintaku Y., Ohkuwa T., Yabe K. (2005) Effects of physical fitness level on postural sway in young children. *Anthropol. Sci.*, 113: 237-244. DOI: 10.1537/ase.040129.
 68. Shumway-Cook A., Woollacott M.H. (1985) The growth of stability: postural control from a development perspective. *J. Mot. Behav.*, 17(2): 131-147. DOI: 10.1080/00222895.1985.10735341.
 69. Son S.C., Meisels S.J. (2006) The relationship of young children's motor skills to later school achievement. *Merrill Palmer Quart.*, 52(4): 755-778. DOI: 10.1353/mpq.2006.0033.
 70. Sundermier L., Woollacott M., Roncesvalles N., Jensen J. (2001) The development of balance control in children: comparisons of EMG and kinetic variables and chronological and developmental groupings. *Exp. Brain Res.*, 136(3): 340-350. DOI: 10.1007/s002210000579.
 71. Usui N., Maekawa K., Hirasawa Y. (1995) Development of the upright postural sway of children. *Dev. Med. Child Neurol.*, 37(11): 985-996. DOI: 10.1111/j.1469-8749.1995.tb11953.x.
 72. Venetsanou F., Kambas A. (2011) The effects of age and gender on balance skills in preschool children. *Phys. Educ. Sport*, 9: 81-91.
 73. Verbecque E., da Costa P.H., Meyns P., Desloovere K., Vereeck L., Halleman A. (2016) Age-related changes in postural sway in preschoolers. *Gait Posture*, 44: 116-122. DOI: 10.1016/j.gaitpost.2015.11.016.
 74. Walker S.P., Wachs T.D., Gardner J.M., Lozoff B., Wasserman G.A., Pollitt E., Carter J.A., International Child Development Steering Group (2007): Child development: risk factors for adverse outcomes in developing countries. *The Lancet*, 369: 145-157. DOI: 10.1016/S0140-6736(07)60076-2.
 75. Walker S.P., Wachs T.D., Grantham-McGregor S., Black M.M., Nelson C.A., Huffman S.L., Baker-Henningham H., Chang S.M., Hamadani J.D., Lozoff B., Gardner J.M., Powell C.A., Rahman A., Richter L. (2011) Inequality in early childhood: risk and protective factors for early child development. *The Lancet*, 378: 1325-1338. DOI: 10.1016/S0140-6736(11)60555-2.
 76. Wassenberg R., Feron F.J.M., Kessels A.G.H., Hendriksen J.G.M., Kalf A.C., Kroes M., Hurks P.P.M., Beeren M., Jolles J., Vles J.S.H. (2005) Relation between cognitive and motor performance in 5- to 6-year-old children: results from a large-scale cross-sectional study. *Child Dev.*, 76(5): 1092-1103. DOI: 10.1111/j.1467-8624.2005.00899.x.
 77. Weisglas-Kuperus N., Baerts W., Smrkovsky M., Sauer P.J. (1993) Effects of biological and social factors on the Cognitive Development of very low birth weight children. *Pediatrics*, 92(5): 658-665.
 78. Wrobel J. (2004) „Vom Kopf auf die Füße stellen Ellipsis“. Die Bedeutung von Bewegung für das Lernen, *Praxis der Psychomotorik*, 29: 204-208.
 79. Zernicke R.F., Gregor R.J., Cratty B.J. (1978) Qualification of postural stability in normal children. In: E. Asmussen and K. Jorgensen (eds.) *Biomechanics VI-A*. University Park Press, Baltimore, pp. 130-134.
 80. Zernicke R.F., Gregor R.J., Cratty B.J. (1982) Balance and visual proprioception in children. *J. Hum. Mov. Stud.*, 8: 1-13.

Received 01.03.2018

Accepted 23.07.2018

© University of Physical Education, Warsaw, Poland