Effect of sensorimotor training on the balance and postural stability of preschool children

Abstract of PhD Thesis

Zsolt Csirkés

Doctoral School of Sport Sciences
University of Physical Education

Supervisor: Dr. Pál Hamar, professor, DSc

Official reviewers: Dr. Sarolta Fest, college professor, PhD

Bartusné Dr. Márta Szmodis, associate professor, PhD

Head of the Final Examination Committee:

Dr. László Tóth, associate professor, PhD

Members of the Final Examination Committee:

Dr. Gyöngyvér Prisztóka, associate professor, CSc

Dr. Gabriella Trzaskoma-Bicsérdy, senior lecturer, PhD

Budapest

2020

INTRODUCTION

Movement itself is a miracle. After birth, the child explores the world around him through movement, which helps him control his body. Movement is the first language a child learns. Not only does exercise make young children physically strong, it affects all areas of their development.

The psychological conditions necessary for the development of equilibrium competence have already been given in early childhood and kindergarten. Therefore, changes in cognitive abilities, speech, behavior and perception provide a good basis for targeted balance development. In addition, we need to pay attention to the motivational aspects as successful development work for the 3-7 age group is only possible in the context of game.

As the leader of the Budai Tornász Műhely (BTM), a recreational gymnastics club for children, I launched preschool gymnastics classes in the fall of 2010 with the aim of providing a place in the 1st district of Budapest for preschool children with various developmental therapy gym equipment without any performance constraints. During the parental needs survey, I found that there was a great need for this kind of physical activity in the district. As the population grew in size, separate groups were formed according to the age-specific characteristics and the level of knowledge of the children. During the trainings, there were also preterm preschoolers among the children, who were initially developed with greater attention and differentiation. During the playful sessions, I noticed that preterm children became more adept at tasks requiring a high degree of balance. Of course, these were observations in which subjectivity played a major role. Therefore, I decided to use objective methods to map the state of the child's balancing ability, that is, the maturity level of their nervous system, using static and dynamic balance tests and postural stability tests. Furthermore, I aimed to improve the static and dynamic balance and postural stability of the subjects during a six-month period of sensorimotor training based on the principles of Ayres therapy using instability training devices.

OBJECTIVES

I aimed to improve the static and dynamic balance and postural stability of preschool children through six months of balance training based on the principles of Ayres therapy, using instability training devices.

Questions for the study

1. What effect does the six-month balance training programme using instability training devices have on the static and dynamic balance and postural stability of preschool children?
2. As a result of the six-month balance training programme, do the balance values of preschoolers born with biological risk factors differ from the values of their peers born with biological risk factors?
3. After six months of balance training, do preschoolers born with biological risk factors catch up with their peers with no risk factors and not attending the training in terms of static and dynamic balancing ability and postural stability?

Hypotheses of the study

1. I hypothesized that after the post test there would be an improvement in the static and dynamic balancing ability and postural stability in the experimental group and in the two control groups compared to the pre test.
2. I hypothesized that as a result of six months of sensorimotor balance development the balancing ability of the preschoolers actively involved in the development and born with biological risk factors improve more compared to their peers with risk factors but not attending the training.
3. I hypothesized that as a result of six months of sensorimotor balance development the static and dynamic balance and postural control values of the preschoolers participating in the development would come near to the values of their peers born without risk factors and not attending the training.

METHODS

Test protocol

There were three groups of preschoolers in the study, only one of whom participated in a six-month 2x30 minute sensorimotor training session per week. The other two groups followed the regular physical education schedule for six months. Before and after six months of development, the static and dynamic balance and postural stability of all three groups were measured.

Test subjects

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 (VR, n = 17, mean age 5.31 ± 0.55; height 115 ± 0.06; body weight 20.71 ± 3.50; birth weight 3009.41 ± 683.63; gestational week 37, 58 ± 2.83; Apgar value 9.05 ± 0.65) in which preschoolers born with biological risk factors attended a 6-month sensorimotor balance intervention based on Ayres therapy; control group I (KR, n = 23, mean age 5.53 ± 0.51; height 120 ± 0.04; body weight 20.52 ± 2.35; birth weight 2961.30 ± 694.04; gestational week 37, 94 ± 4.09; Apgar value 8.56 ± 1.23), in which individuals born with biological risk factors did not attend the training; control group II (KI, n = 24, mean age 5.70 ± 0.39; height 122 ± 0.02; body weight 21.78 ± 1.63; birth weight 3199.79 ± 298.34; gestational week 39.73 ± 0.73; Apgar value 9.50 ± 0.51), in which children born without biological risk factors also did not attend the six-month balance development. Children born with biological risk factors were divided into two groups (VR and KR) by a simple random sampling.

Testing procedures and instrumentation

Static balance tests

The static balance tests were performed on the edge of a special balancing board which proved to be suitable for the static balance of the body.

1. Standing balance test on one leg with open eyes

Field of application: measurement of static balance of the body.
Equipment: stopwatch, 50 cm long, 10 cm high and 2 cm wide fixed board.
Execution: The subject puts his hands on his hips, with one foot on the wooden cube that holds the board and the other foot on the edge of the board. He lifts his foot from the board and tries to keep his balance for up to 60 seconds. It is a mistake to take his hands off the hips, step off the board, touch the ground with the raised foot, or put the raised foot on the support leg to maintain balance. The stopwatch is triggered when the child has raised his leg.

Evaluation: The average of the two better time results from three attempts counts to an accuracy of 0.01 sec. Our comments are noted (eg. in order to avoid any injury, help is required).

2. 2x20 sec standing balance test on one leg with closed eyes

Field of application: measurement of static balance of the body.
Equipment: stopwatch, 50 cm long, 10 cm high and 2 cm wide fixed board.
Execution: The subject puts his hands on his hips, with one foot on the wooden cube that holds the board and the other foot on the edge of the board. He raises his foot from the board and balances with his eyes closed and tries to keep his balance for up to 20 seconds. It is a mistake to open his eyes, take his hands off your hips, step off the board, touch the ground with his raised foot, or put his raised foot on the support leg to maintain balance. The stopwatch is triggered when the child has lifted his leg and closed his eyes.

Evaluation: Based on two attempts, the total time of balancing counts to an accuracy of 0.01 sec. Maximum value is 40 sec. Our comments are noted (eg. in order to avoid any injury, help is required).

Dynamic balance tests

Dynamic balance tests were performed on low balance beams and edges of balancing boards, which proved to be suitable for the dynamic balance of the body.

1. Beam walking test with open eyes

Field of application: measurement of dynamic body balance.

Equipment: Stopwatch, 2 pieces of low balance beams put together. Each beam is 10 cm high, 5 cm wide and 1.5 m long with two marked lines between the 2 m section.

Execution: The participant starts with the command "Start" and has 45 sec to cover the longest distance on the beams by walking forward 2 meters from one end to a sign on the beam marking the end of the 2 m section and has to turn back the other way beyond this mark. In case of stepping down within 45 seconds, the attempt is considered to be completed.

Evaluation: To calculate the final result, the two attempts (distances) were added together (total distance of walking with an accuracy of 0.5 m and overall time of walking with an accuracy of 1 sec). Our comments are noted (eg. in order to avoid any injury, help is required).

2. Walking test on balance boards with open eyes

Field of application: measurement of dynamic body balance.

Equipment: 6 pieces of 50 cm long, 10 cm high and 2 cm wide wooden boards placed hexagonal on the ground.

Execution: The test person stands with one foot on one of the wooden cubes and places the other foot on the edge of the board. Then he starts with the command "Start" on the edges of the boards so that he can move only one foot to each edge. In case of stepping off the box or if both feet touch the same edge or he steps back the attempt is considered to be completed. The subject is allowed a trial run.

Evaluation: the number of steps to the first error (pieces). The total distance between the two attempts counts. Our comments are noted (eg. in order to avoid any injury, help is required).

Stabilometric tests for postural stability

The stabilometer used is the property of the Department of Kinesiology, University of Physical Education. The platform was originally a German patent for Bretz-König and has been further developed. The platform has a linearity and a hysteresis of 1.5% and a horizontal resolution of 1 mm. Connecting devices can be any personal computer that can receive these signals. It measures 50x50 cm and weighs 15 kg.

1. Romberg tests with open and closed eyes: Two Romberg tests were used, one with open eyes and the other with eyes closed. The subject stands up on the platform, with the leg closed, with the body straight, extending his arm forward, palms down, and trying to stay as balanced as possible for up to 20s.

2. Posturography tests: four joyful tests were used to examine postural stability.

Center: The subject stands up to the platform in front of the monitor, shoulder-width apart, and tries 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 programme examines what percent of the tested time the square is fixed in the center.

Christmas tree: The subject stands up to the platform in front of the monitor, shoulder-width apart, and tries to maintain balance by picking 6 bonbons from a Christmas tree seen on the screen. A maximum of 20 seconds is available for the task. The test is evaluated on the basis of an attempt with an accuracy of 1% of success and 1 second of elapsed time.

Mouse in the hole: The subject stands up to the platform in front of the monitor, shoulder-width apart, and tries to maintain balance by moving a mouse seen on the screen into an asymmetrically positioned hole. A maximum of 20 seconds is available for the task. The test is evaluated on the basis of an attempt with an accuracy of 1 second of the elapsed time.

Square painting: The subject stands up to the platform in front of the monitor, shoulder-width apart, and tries to balance by painting a square seen on the screen. A maximum of 20 seconds is available for the task. The program examined two pieces of data: what percentage of the square in the center of the screen is painted, and what percentage of the given time the center of gravity remains inside the target frame.

Sensorimotor development based on the principles of Ayres therapy

The sensorimotor balance sessions were held in a 15x15 meter gym in the city center of Budapest, with the help of three instructors (one skilled P.E. teacher and two graduate students in MA of the University of Physical Education). Prior to the sessions, with the assistant trainers, the location of the stations and the tasks to be performed were planned based on the research plan. We set up four stations that were cheerfully named to the age of the children: Bouncing flea, Flying rubber belt, Colorful gummy berries and Magical rubber forest.

At each station, we determined 5 developmental levels to be achieved, marked with different colors: white level was the easiest, orange level is easy, green level is medium, blue level is difficult and purple level is the most difficult. The performance requirements for each task at each level were determined. This means that the child can change the level (color) only if he or she has fulfilled the requirements of the previous level. We uniformly determined that the child must meet the level requirements 4-6 times before proceeding. The requirements are designed so that every child can find the level that suits his or her abilities and, if he or she is very skilled, he or she will be able to get to the most difficult one.

We also paid attention to creating a safe environment for performing our tasks. All stations were spaced sufficiently apart, and exercise mats were placed around and below the stations to increase the safety of children and prevent unexpected falls.

The children participated in 2x30 minute sessions per week for 6 months. Before the first developmental session, we handed over to the parents a booklet detailing the purpose, requirements, and tasks of each level of the development. The child always brought this booklet and took it home at the end of the session. The booklet was dated when completing the levels, so the parent could track the progress of their child. Instructors recorded it on a separate sheet when the child completed a level. Originally a black and white booklet over time, was full of color drawings.

During the first two weeks of the session, baseline levels were determined for each child at each station. These initial levels are written in the booklet. It turned out that at "Bouncing flea" station, 65% of the children started at easy (orange) and 35% started at medium (green) level. At the "Flying rubber belt" station, 53% of children started at easy (orange) and 47% at medium (green) level. At the "Colorful gummy berries" station, preschoolers started with four levels of difficulty. 11.5% of participants started the session at the easiest (white), 59% at the easy (orange), 18% at the medium (green) and 11.5% at the difficult (blue) level. At the "Magical rubber forest" station, 6% of participants started at the easiest (white), 70.5% at the easy (orange) and 23.5% at the medium (green) level.

Questionnaire on changes in the movement quality of the child

During the half-month of the six-month sensorimotor intervention, parents of the preschoolers born with biological risk factors completed a questionnaire about the changes of the movement quality of their child. The questionnaire included nine questions with open and closed versions. For the latter one more choices were possible.

Applied statistical methods

The results of the subjects were analyzed according to the three large groups of subjects. Differences between the groups' results at the input measurements and the results at the second measurements were tested by One-way ANOVA, using the F-test or Welch-test, depending on the fulfillment of the scattering homogeneity. Of the Post hoc tests, LSD was used for the variance homogeneity test and Tamhane's T2 test for the non-metered test. To test for differences between the results of measurements 1 and

2, the paired samples t-test was used. To test the assumptions needed to perform t-tests, I first performed normality and standard deviation homogeneity tests. In those cases where the conditions were not met, a non-parametric test was used, and in these exercises the Wilcoxon test was used to test for differences in performance between the two measurements. Descriptive statistics of the results of the various measurements and Pearson correlations between the variables were also calculated. The results were analyzed at a significance level of 0.05.

RESULTS

ANOVA analysis of pre test scores:

The Levene test alone showed a significant difference between groups' standard deviations (L = 4.709; p = 0.013). Therefore, in this case, a Welch test was performed, whereas for all other measurements where standard deviation homogeneity is met, the significance of the F-statistic informs about the test result.

The values indicate a significant difference between the groups' average performance in four exercises:

- Standing balance test on one leg with open eyes - (F = 5.462; p = 0.007)
- Walking test on balance boards with open eyes - (F = 3.149; p = 0.049)
- Romberg tests with open eyes - (F = 3.781; p = 0.028)
- Posturography test - ’Square painting’ (success,%) - (F = 4,027; p = 0.023)

The results of the LSD post hoc tests revealed that in all four tests the KI group showed superiority over one of the risk groups.

ANOVA analysis of post test scores:

The Levene test showed significant differences between the standard deviations of the ’Centrum success’ (L = 5.188; p = 0.008) and the ’Square painting prorated success’ (L = 9.645; p <0.001). In these cases, we again performed the more robust Welch test to compare the means of the groups in a professional manner. In all other cases, the value and significance of the F-statistic can still be examined.

In Romberg test with open eyes there is a significant difference between groups' mean performance - ($F = 3.374$; $p = 0.041$).

Results of static balance tests:

1. Standing balance test on one leg with open eyes

VR pre test vs. VR post test

Significant difference was found between pre and post test scores ($p = 0.025$).

KR pre test vs. KR post test

No significant difference was found between pre and post test scores ($p = 0.088$).

KI pre test vs. KI post test

No significant difference was found between pre and post test scores ($p = 0.826$).

2. 2x20 sec standing balance test on one leg with closed eyes

VR pre test vs. VR post test

No significant difference was found between pre and post test scores ($p = 0.679$).

KR pre test vs. KR post test

No significant difference was found between pre and post test scores ($p = 0.203$).

KI pre test vs. KI post test

Significant difference was found between pre and post test scores ($p = 0.003$).

Results of dynamic balance tests:

1. Beam walking test with open eyes

VR pre test vs. VR post test

Significant difference was found between pre and post test distance scores ($p = 0.05$). No significant difference was found between pre and post test time scores ($p = 0.190$).

KR pre test vs. KR post test

No significant difference was found between pre and post test distance scores (p = 0.189). No significant difference was found between pre and post test time scores (p = 0.513).

KI pre test vs. KI post test

No significant difference was found between pre and post test distance scores (p = 0.174). No significant difference was found between pre and post test time scores (p = 0.533).

2. Walking test on balance boards with open eyes

VR pre test vs. VR post test

Significant difference was found between pre and post test scores (p = 0.006).

KR pre test vs. KR post test

Significant difference was found between pre and post test scores (p = 0.001).

KI pre test vs. KI post test

Significant difference was found between pre and post test scores (p = 0.003).

<u>*Results of stabilometric tests*</u>

1. Romberg test with open eyes

VR pre test vs. VR post test

No significant difference was found between pre and post test scores (p = 0.356).

KR pre test vs. KR post test

No significant difference was found between pre and post test scores (p = 0.600).

KI pre test vs. KI post test

Significant difference was found between pre and post test scores (p = 0.029).

2. Romberg test with closed eyes

VR pre test vs. VR post test

No significant difference was found between pre and post test scores (p = 0.185).

KR pre test vs. KR post test

No significant difference was found between pre and post test scores (p = 0.670).

KI pre test vs. KI post test

No significant difference was found between pre and post test scores (p = 0.714).

3. "Center" test

VR pre test vs. VR post test

Significant difference was found between pre and post test scores (p = 0.011).

KR pre test vs. KR post test

Significant difference was found between pre and post test scores (p = 0.015).

KI pre test vs. KI post test

Significant difference was found between pre and post test scores (p = 0.011).

4. "Christmas tree" test

VR pre test vs. VR post test

No significant difference was found between pre and post test success and time scores (p = 0.180; p = 0.165).

KR pre test vs. KR post test

No significant difference was found between pre and post test success and time scores (p = 0.059; p = 0.255).

KI pre test vs. KI post test

No significant difference was found between pre and post test success and time scores (p = -; p = 0.422).

5. "Mouse in the hole" test

VR pre test vs. VR post test

Significant difference was found between pre and post test scores (p = 0.004).

KR pre test vs. KR post test

Significant difference was found between pre and post test scores (p = 0.004).

KI pre test vs. KI post test

Significant difference was found between pre and post test scores (p = 0.014).

6. "Square painting" test

VR pre test vs. VR post test

Significant difference was found between pre and post test prorated success and success scores ($p = 0.023$; $p = 0.011$).

KR pre test vs. KR post test

No significant difference was found between pre and post test prorated success and success scores ($p = 0.433$; $p = 0.167$).

KI pre test vs. KI post test

No significant difference was found between pre and post test prorated success and success scores ($p = 0.165$; $p = 0.572$).

<u>*Interaction effects of different tests*</u>

VR group

Of 34 cases during the pre test, in five cases the strength of relationship was weaker than average ($0.31 \leq |r| \leq 0.49$), in 28 cases were stronger than average ($0.51 \leq |r| \leq 0.8$), and in one case explicitly strong ($0.81 \leq |r| \leq 0.99$). The strongest positive correlation was noticed between the balance beam distance and balance beam time ($r = 0.83$; $p < 0.001$).

Of 13 cases during post test, in two cases the strength of relationship was weaker than average, in ten cases were stronger than average, and in one case also a very strong correlation was observed. In this case as well, the strongest positive correlation was noticed between the balance beam distance and balance beam time ($r = 0.854$; $p < 0.001$).

KR group

Of 26 cases during the pre test, in six cases the strength of relationship was weaker than average ($0.31 \leq |r| \leq 0.49$), in 18 cases were stronger than average ($0.51 \leq |r| \leq 0.8$), and in 2 cases explicitly a strong correlation was observed ($0.81 \leq |r| \leq 0.99$). The strongest directionally positive correlation, as in the case of the VR group, is also found between balance beam distance and balance beam time ($r = 0.859$; $p < 0.001$). A negative correlation was found between Romberg test with open eyes and "Center" test ($r = -0.832$; $p < 0.001$).

Of 11 cases during post test, in four cases the strength of relationship was weaker than average, in one case was moderate (Standing balance test on one leg with open eyes - Romberg test with open eyes ($r = -0.5$; $p = 0.015$)) and in 6 cases stronger than average.

KI group

Of 10 cases during pre test, in six cases the strength of relationship was weaker than average ($0.31 \leq | r | \leq 0.49$), in 3 cases was stronger ($0.51 \leq | r | \leq 0.8$), but in one case extremely strong ($0.81 \leq | r | \leq 0.99$). The strongest positive correlation was found between the balance beam distance and balance beam time ($r = 0.88$; $p < 0.001$), similarly to the results of the other two groups.

Of 10 cases during post test, in five cases the strength of relationship was weaker than average, in five cases was stronger.

Level changes of the experimental group (VR) at four stations of the sensorimotor development

At the "Bouncing flea" station, four preschoolers managed to advance to a higher level. Two children were able to switch from easy orange to medium green level, and two preschoolers from medium green to difficult blue.

11 participants were able to improve their performance at the "Flying rubber belt" station. Five preschoolers was able to switch from easy orange to medium green, and from medium green to difficult blue, and one from easy orange to difficult blue.

At the "Colorful gummy berries" station, four children could get to a higher level. Three from easy orange to medium green, and one from medium green to difficult blue.

At the "Magic rubber forest" station, eight individuals were able to advance to a higher level. Five from easy orange to medium green, and three from medium green to difficult blue. At each station there were children who could not advance to a higher level during the six-month balance training.

CONCLUSIONS

1. I consider my first hypothesis to be valid for both static and dynamic balance tests. Based on the scores of the Romberg tests, this hypothesis was partially confirmed, since in the case of Romberg test with open eyes, the KR group, in case of Romberg test with closed eyes, both the KR and the KI groups produced less body swing, however. In the case of posturography tests, the first hypothesis has been validated numerically, with only a decrease in the "Square painting success" of the KI group.

2. I consider my second hypothesis to be valid for the "Standing balance test on one leg with open eyes" and the "Beam walking test". For the "2x20 sec standing balance test on one leg with closed eyes" and the "Walking test on balance boards with open eyes", I reject this hypothesis, because the KR group showed greater development. In the case of the Romberg tests with open and closed eyes, I reject my hypothesis because the VR group's body swings increased. When examining the results of the posturography tests, I consider this hypothesis partially validated, as the VR group's balance values improved more for the variables "Center", "Mouse in the hole", "Square painting success" and "Square painting prorated success". In the case of "Christmas tree success" and "Christmas tree time," the VR group performed numerically poorer.

3. My third hypothesis is valid for both static balance tests, the "Walking test on balance boards with open eyes", the "closed-eye Romberg test", and all four posturography tests; I reject it for the "Beam walking test" and the "open-eye Romberg test". In four of the six variables, the VR group performed better than the KI group.

LIST OF OWN PUBLICATIONS

Original publications in the topic of the dissertation:

Csirkés Zs, Jakab K, F Földi R, Hamar P. (2018) Hat hónapos szenzomotoros fejlesztő torna hatása a biológiai rizikófaktorral született 5-6 éves óvodások dinamikus egyensúlyozó képességére. Magyar Sporttudományi Szemle, 76: 19-29.

Csirkés Zs, Bretz K, Jakab K, F Földi R, Hamar P. (2018) Effects of a 6-month balance intervention on postural control of preschoolers born with biological risk factors. Biomedical Human Kinetics, 10: 107-117.

Csirkés Zs, Bretz K, F Földi R, Hamar P. (2018) Effects of instability training devices on dynamic balance in preschoolers born with biological risk factors. Early Child Development and Care, Published online 19 Feb 2018.

Csirkés Zs, Hamar P. (2015) Az óvodapedagógusok mozgásfejlesztéssel kapcsolatos szemléletének összehasonlító vizsgálata. Fejlesztő Pedagógia, 26(4-6): 37-45.

Csirkés Zs, Ramocsa G, F Földi R, Bretz K, Hamar P. Az Ayres-féle terápián alapuló mozgásfejlesztés a biológiai rizikófaktorral született óvodások körében. In: Borbély A, Hamar P, Kotányi M (szerk.). Színes sporttudomány - Tanulmányok a 45. Mozgásbiológiai Konferencia Előadásaiból. Debreceni Campus Nonprofit Közhasznú Kft., Debrecen, 2015: 248-258.